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A NEW SYSTEM OF IMPACT EXCITATION OF CONTINUOUS ELECTRICAL OSCILLATIONS AND THEIR APPLICATION TO WIRELESS TELEPHONY.

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[During the development of radio-telegraphy and radio-telephony there have appeared many devices, including various forms of discharge gaps and arcs, for the production of high-frequency oscillations. The following contribution presents yet another method, which was discovered by the author, for the production of oscillatory currents of high frequency; an arrangement which at first sight may appear to differ but slightly from some hitherto known systems, but which, on closer study, will be seen to be new in electrical action. Besides being new, this system possesses some interesting characteristics and some advantages over the other systems, which render it useful. A brief study[1] of the system is given in the following pages, together with some notes on its successful application to wireless telephony.]

IF an ordinary spark discharge of a condenser takes place in a primary circuit, which is coupled to a closed or open secon-

[1] For a more detailed study see "A New Method of Impact Excitation of Undamped Oscillations and Their Analysis by Means of Braun-Tube Oscillographs," by E. L. Chaffee, *Proceedings American Academy of Arts and Sciences*, vol. xlvii, No. 9, Nov., 1911.

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dary circuit, there are produced in the two circuits oscillations of two periods. These two periods result from the interaction of the currents in the two circuits, causing the energy to be alternately interchanged from one circuit to the other. Since we are chiefly interested, in this discussion, in the conditions which give a maximum amplitude of current in the secondary circuit, the two circuits are to be considered as adjusted to the same natural period. Fig. 1 (*a*) shows the graph of the currents in the primary and secondary circuits for the case just considered.

The disadvantages of the ordinary spark-discharge system are obvious. The periodic return of energy into the primary circuit causes a useless dissipation of heat in the spark gap, and, aside from the wear and tear on the gap, the efficiency of the system is greatly reduced. The double periodicity of the oscillations is undesirable in wireless telegraphy not only because the energy is divided between the two periods, but because of the greater interference of signals.

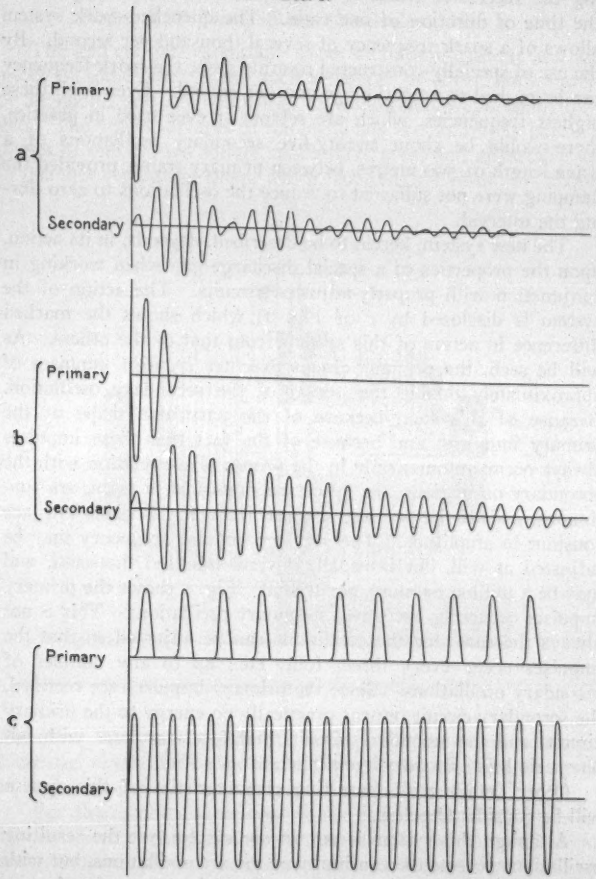
A marked improvement over the ordinary spark-discharge system is found in the quenched-spark method of producing oscillations. The Lepel system [2] is an example of this class of generators. The success of this system depends upon the properties of certain, short, rapidly-cooled gaps which are characterized by a loss in conductivity as soon as the amplitude of the oscillations in the primary circuit becomes zero; but this loss in conductivity is, in general, *not* rapid enough to quench out the primary oscillations when the current alone becomes zero. After the primary circuit ceases to oscillate, the secondary circuit continues to vibrate in its natural period. The graphs of the oscillations for this system are shown at *b*, Fig. 1.

The secondary oscillations of the quenched-spark system are of three periods; namely, the two coupling periods when the primary is active, and the natural period of the secondary circuit after the primary oscillations have been quenched.

The diagrams given at *a* and *b* of Fig. 1 represent the conditions for only one oscillation train. In the case of the first system, the spark or train frequency is only a few hundred per

[2] Lepel, *Electrician* (London), 63, pp. 142, 157, 174, 345, 376 (1909); 64, pp. 153, 386 (1909–10); G. W. Nasmyth, *Phys. Rev.*, 32, No. 1, 103 (1911). Peukert arc, *Electrician* (London), 64, 361, 550.

FIG. 1.


a
Primary
Secondary
b
Primary
Secondary
c
Primary
Secondary

second, which means that, in general, the interval of time separating the successive trains is several hundred times longer than the time of duration of one train. The quenched-spark system allows of a spark frequency of several thousand per second. By the use of specially-constructed rotating gaps, the spark frequency can be pushed to 20,000 or 30,000 per second. Even with these highest frequencies, which are seldom if ever used in practice, there would be about twenty-five secondary oscillations of a wave length of 500 metres, between primary trains, provided the damping were not sufficient to reduce the oscillations to zero during the interval.

The new system, herein to be described, depends, in its action, upon the properties of a special discharge gap when working in conjunction with properly-adjusted circuits. The action of the system is disclosed by *c* of Fig. 1, which shows the marked difference in action of this system from that of the others. As will be seen, the primary circuit executes *rectified* impulses of approximately double the period of the secondary oscillation. Because of this fact, because of the particular shape of the primary impulses, and because of the fact that these impulses always occur automatically in the proper phase relation with the secondary oscillations, the latter are sinusoidal in form, are continuous, and, if the primary impulse frequency be sufficient, are constant in amplitude. The primary impulse frequency may be adjusted at will, but is usually several hundred thousand, and may be a million or more, per second. Fig. 1 shows the primary impulses occurring every two secondary oscillations. This is not always the case, for the conditions can be adjusted so that the impulses occur every three, four, etc., up to any number of secondary oscillations. Since the primary impulses are rectified, the secondary circuit returns practically no energy to the primary circuit, and the secondary circuit, therefore, oscillates with but one period, *i.e.*, its own free period.

Other details and interesting characteristics of this system will be considered below.

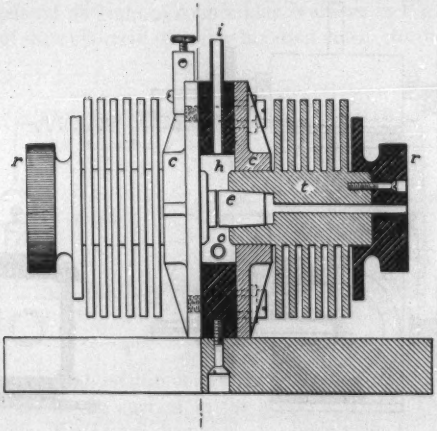
Although this system is not an arc system, yet the resulting oscillations possess the continuity of the arc oscillations, but with a greater constancy of wave length and an improvement of wave form. A more detailed comparison with the Poulsen-arc system will be found in the section on wireless telephony.

THE OSCILLATORY SYSTEM.

(1) *The Gap and Connections.*

The gap consists essentially of an aluminum cathode and an anode of some other metal, such as copper or silver, both water or air cooled and surrounded by an atmosphere of moist hydrogen. The active surfaces of the terminals are accurately parallel planes of one or two square centimetres area, and adjustable as to distance separating them, which, for the best results, is about

FIG. 2.



Air-cooled *Cu-Al* discharge gap. One-half natural size.

.07 mm. Large terminals are undesirable on account of the increased electrostatic capacity of the gap, which must be small in comparison with the main capacity of the circuit.

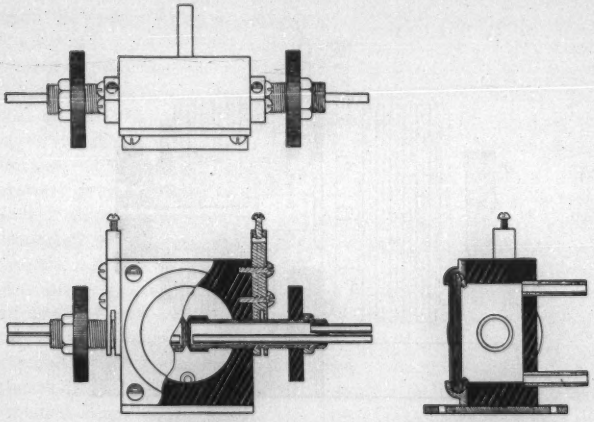
For the cathode, aluminum is the only metal which gives at all satisfactory results, and the gap should be constructed so that the terminals can be occasionally renewed. After the gap has been in operation for some time the aluminum becomes pitted and covered with a very hard oxide which is difficult to remove. One electrode was operated, however, for over one

hundred hours with fairly satisfactory results at the expiration of that time.

Several metals work well as anode, the latter apparently playing very little part in the action of the gap. It appears, however, that the denser metals of high cathode drop, such as copper and silver, are desirable. The anode, with occasional cleaning, will serve indefinitely.

Although the amount of heat produced in the gap is small, some method of cooling the terminals is necessary. Air cooling

FIG. 3.



Details of water-cooled *Cu-Al* gap. Two-fifths natural size.

by means of radiating vanes is to be preferred on account of convenience and simplicity. Fig. 2 gives the details of an air-cooled gap, the right-hand half in section. At *e* there is shown the *Al* electrode which is held by a taper-fit in the massive terminal *t*. Opposed to this *Al* electrode is a similarly shaped copper electrode held by taper-fit in a similar massive terminal. These terminals are threaded and engage in the side castings *c c*, and are provided with blackened metallic radiating vanes as shown. The side castings are separated by a thin slab of hard

rubber or asbestos board, which has a central circular hole to serve for the gap chamber *h*. Rubber handles *r r* are for use in adjustment. The inlet and outlet for the hydrogen are shown at *i* and *o*.

A water-cooled gap as shown in Fig. 3 was, however, used throughout this investigation. By reference to the drawing this gap is seen to consist of two hollow threaded electrodes capped with aluminum and copper, respectively, and each provided at the outside end with an inlet and outlet tube for the passage of the cooling water. The terminals are enclosed in a hard rubber casing provided with a circular glass front. Hard rubber disks attached to the electrodes serve for adjusting handles.

The general diagram of connections is shown in Fig. 4. *S* is a source of direct current of a few hundred volts. In the follow-

FIG. 4.

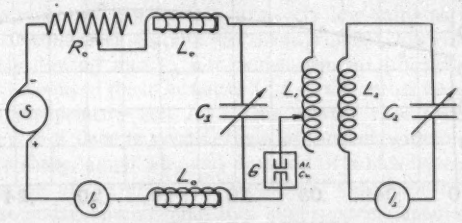


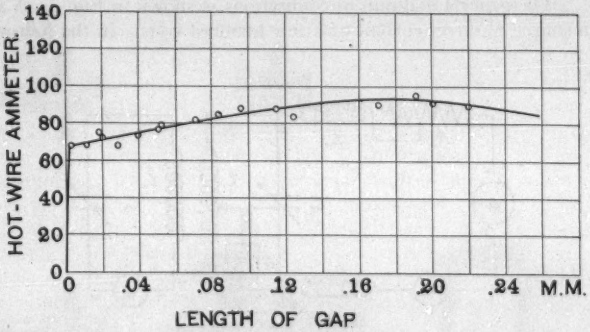
Diagram of connections.

ing experiments about 500 volts were used. I_0 is a D. C. ammeter which measures the current in the supply circuit. This circuit also contains the two inductances or choke coils L_0 L_0, and a variable resistance R_0, capable of reducing the current to about 0.2 ampere. In the following experiments L_0 L_0 are ordinary A. C. arc-light inductances, and R_0 is a resistance, adjustable in one-half ampere steps, in series with a variable copper-sulphate electrolytic resistance, for closer regulation of current. C_1 and C_2 are variable air condensers, G the gap, L_1 and L_2 the variable primary and secondary of the closely-coupled oscillation transformer, and I_2 a hot-wire ammeter. The secondary circuit is here shown as a closed circuit, but an open antenna circuit may be used.

(2) *Operation of Gap.*

The system will start on closing the switch if the distance between the terminals is not much greater than 0.1 mm. In appearance the discharge resembles a very minute arc, of an intense reddish-purple color, absolutely quiet and stationary. The discharge remains at one point on the electrodes for several minutes until the aluminum is slightly pitted, when it suddenly shifts to another point. When the discharge is examined by means of a spectroscope only the primary hydrogen spectrum appears with an occasional weak flashing-up of a few of the

FIG. 5.



Effect of changing length of gap.

$I_0 = .335$ ampere.
$\lambda_2 = 106$ meters.
$C_1 = 112 \times 10^{-5}$ $\mu.f.$
$C_2 = 60 \times 10^{-5}$ $\mu.f.$

aluminum lines. Plate 1*b* gives the discharge spectrum with an aluminum comparison spectrum. It is evident from the figure that the metals are not vaporized, and the indications are that the conduction is entirely by gaseous ionization.

In order to show the effect on the intensity of the secondary oscillations of varying the length of the gap, the curve shown in Fig. 5 was taken. It is seen that the intensity of the secondary current, as measured by the hot-wire ammeter, is roughly independent of the length of the gap. At 0.18 mm. the secondary current is a maximum, but at about this length of the gap the

discharge begins to hiss and become unsteady. For other values of the main current, I_0, the curve would be slightly different, but, in general, the best results are obtained with a gap length of from .04 to .09 mm.

The effect of changing the pressure of the hydrogen was investigated. Apparently atmospheric pressure gives the most satisfactory results, although, for decreased pressure, the oscillations are possibly slightly more intense until the pressure of about 10 or 20 cm. is reached, when they rapidly become weaker. Increased pressure is decidedly detrimental.

The following is a brief review of the events during one cycle, the details of which will be considered more at length later. It is clearest, in tracing the sequence of phenomena, to begin at the instant after the system has been started, when the potential of the primary condenser C_1 (Fig. 4) has attained a value sufficient to break down the high resistance of the gap. The gap resistance rapidly falls to a very low value as the discharge of condenser C_1 and the main current I_0, which was previously flowing into C_1 and which remains practically constant on account of the inductances L_0 L_0, rush across the gap and through the primary coil L_1. This current rush takes place according to a definite positive loop of current with respect to time, the shape, amplitude, and duration of which depend upon the constants of the circuit, the rapidity of absorption of energy by the secondary circuit, and, to a slight extent, upon the conditions of the gap and strength of the main current I_0. The condenser C_1 is discharged and charged somewhat in the opposite direction by this positive current rush. If conditions are right the discharge stops as soon as I_1 becomes zero, there being no inverse current. The secondary receives a certain increment of energy from this discharge, and continues to oscillate after the primary discharge stops.

This absence of inverse current above referred to is due to the combination of three conditions. First, and most important, is the practically instantaneous re-establishment of the high initial gap resistance when the current becomes zero, due probably to the formation of an insulating oxide film on the aluminum; second, the higher cathode drop of the anode metal; third, the absorption of energy by the secondary, although rectification usually takes place without this aid.

At the end of the above-mentioned current rush the current through the gap is zero and the condenser C_1 has an inverse charge. Since the main current must remain constant, it is now flowing into C_1, it having been gradually shifted over to C_1 as I_1 decreased toward zero. The main current I_0 flows into C_1 at a practically constant rate, neutralizing the inverse charge and charging it in the initial direction. The potential difference of C_1 increases uniformly, attaining a much higher value than exists outside the choke coils. This uniform increase in potential of the primary condenser is very useful, as will appear later.

Impressed across the gap is the potential difference of the condenser C_1 plus the ripples induced in the primary circuit by the secondary current, these potential ripples serving as a trigger to start the primary discharge on a second cycle in the proper phase relation with the secondary oscillation.

It is evident from the above consideration that, on account of the inductances L_0, L_0, the condenser C_1 can attain a much higher difference of potential than that of the source, the magnitude of this condenser potential being determined by the breaking-down potential of the gap. It is also clear that, if this breaking-down potential be assumed approximately constant, the number of discharges of C_1 per second depends upon the main current I_0.

The duration of each primary discharge does not, as has been stated, depend upon the supply current, so that it is only the duration of the interval between primary discharges which changes with varying main current. The secondary continues to oscillate during these intervals with decreasing amplitude according to the damping of the secondary circuit. In what follows the number of secondary oscillations to one primary discharge and charge is spoken of as the "inverse charge frequency referred to the secondary oscillation" or simply I. C. F.

From what has been said it is clear that the secondary receives periodic impulses from the primary, the frequency of these impulses depending upon the main current and the capacity of the primary condenser. During the intervals of non-activity of the primary circuit the secondary circuit oscillates in its own free period and with damping determined solely by the conditions of the secondary circuit, such as resistance and radiation. As has been stated, the amplitude of the oscillation can, however,

be maintained practically constant by making the primary impulses occur every two or three secondary oscillations, and, if the damping in the secondary circuit be small, the resulting oscillations are then almost perfectly undamped and continuous.

(3) *The Syntony Conditions.*

In order that the maximum energy be transferred to the secondary circuit there are two conditions of syntony, as they may be termed, to be fulfilled. In the first place, the primary discharges must always occur in the proper phase relation with the secondary oscillation, or, in other words, the I. C. F. must be a whole number. In general the I. C. F. is between 5 and 16 or 20, and this first condition of syntony is automatically forced by the strong reaction of the secondary current upon the primary circuit, but when the I. C. F. is of the order of 2 or 3 the adjustment for this condition of syntony must be more carefully made.

The second condition of syntony is that the *shape* of the primary wave or current rush must be such that the resulting electromotive-force impulses in the secondary circuit, due to the different parts of the primary wave, bear the proper phase relation to the secondary wave. With a fixed secondary circuit the first condition can be obtained by varying the main current I_0, or the primary capacity C_1. The second condition of syntony can be established by changing the primary inductance L_1.

The two conditions of syntony are illustrated by the curves of Figs. 6 and 7. In Fig. 6 the full line curve gives the variations of the secondary current, I_2, plotted to an arbitrary scale, as the main current, I_0, is varied, and shows maxima and minima of I_2 as the first condition of syntony is more or less perfectly fulfilled. The dotted disconnected lines give the maximum wave length readings of the wave meter, excited by the primary discharge, as ordinates plotted to the variable I_0. The third dot-and-dash curve is the reading of the wave meter when set on the primary circuit, and when the secondary circuit is open.

In further explanation of Fig. 6 attention is called to the following facts. It is evident that if the potential to which the condenser is charged is practically the same under all conditions —and experiment shows that this is approximately the case— then with a given C_1, the number of discharges per second in the primary circuit is roughly proportional to the current I_0. This

actual spark frequency produces in the wave meter an effect corresponding to a wave of that frequency. This primary fundamental wave length, as it will be called, plotted to I_0 would give a curve of the general shape given by the dot-and-dash line in the figure. When, however, the secondary circuit is closed the secondary current exerts an equilibrating influence on the primary discharge, helping it to occur, as has been stated, at a definite time in relation to the secondary current, thereby forcing

FIG. 6.

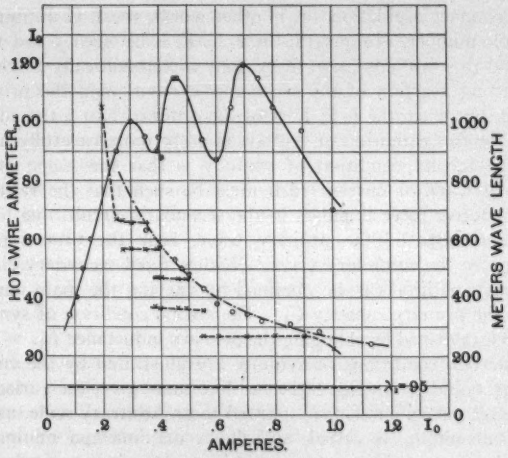


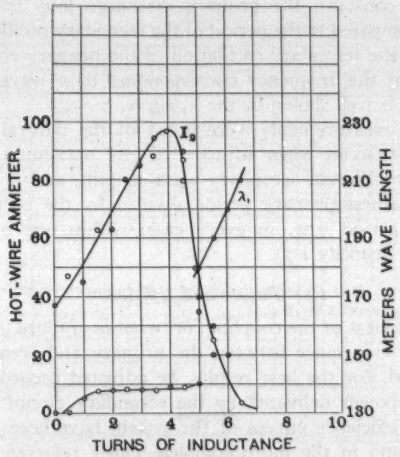
Illustration of syntony to charge frequency.

$\lambda_2 = 95$ metres.
$C_1 = 80 \times 10^{-5}$ μ.f.
$C_2 = 60 \times 10^{-5}$ μ.f.

the primary circuit to operate according to the short horizontal lines. For instance, by reference to the figure it is seen that, for a supply current of 0.7 ampere, the unforced primary fundamental wave length is 350 metres. The frequency corresponding to this is about 860,000 per second, which means that there are that number of primary discharges occurring per second. When, however, the secondary circuit, having a natural wave length, $\lambda_2 = 95$ metres, is closed, conditions are different on account of

the absorption of energy by the secondary circuit, and the primary discharges at a rate corresponding to a wave length of about 280 metres. This is about three times λ_2, showing that the I. C. F. is 3. As the supply current is decreased the primary is forced by the secondary to discharge at this rate until the current has become so small that the slower rates corresponding to I. C. F.'s of 4 or 5 are more stable. When conditions are least

FIG. 7.



Curve showing syntony to wave form.

$\lambda_2 = 86$ metres.
$I\delta = .75$ ampere.
$C_1 = 60 \times 10^{-6}$ μ.f.
$C_2 = 40 \times 10^{-6}$ μ.f.

forced for these values of I. C. F. a maximum of secondary current is observed as shown at $I_0 = 0.46$ in the figure. It is seen that for the steep part of the dot-and-dash curve the I. C. F. jumps between several successive values. It is also now easy to understand that the maxima of secondary current naturally occur at values of I_0 where the I. C. F. is less forced.

The second condition of syntony, namely, the syntony of wave form, is represented in Fig. 7. In this case the hot-wire

ammeter reading was taken in the secondary circuit as an inductance, in series with the primary of the oscillation transformer, was varied, the abscissa scale being in turns of the coil. A variation of this inductance changes the natural period of the primary circuit, thus affecting the time of duration of the primary impulses without materially changing their frequency. The disconnected curve, marked λ_1, represents the primary fundamental wave length plotted to turns of inductance. The curve of secondary current shows the marked maximum when, the I. C. F. remaining constant, the primary discharge loop has the best duration compared to the period of the secondary oscillation. The forcing by the secondary oscillation of the primary condenser to discharge at the frequency corresponding to a wave length of 138 meters is well shown by the λ_1 curve.

Several measurements were taken of the natural period of the primary circuit when adjusted to give maximum secondary current, for different secondary wave lengths, and it was found that this natural primary period divided by the corresponding secondary period was, in every case, within one or two per cent. of the quantity 1.71.

(4) *Power and Efficiency.*

The closeness of the coupling, or, what is of more importance, the mutual inductance between the primary and secondary circuits, should, for the best results, be adjusted according to the amount of power delivered by the secondary circuit. Various power and efficiency curves of the system have been taken and may be found in the more complete paper referred to above. Only a few general deductions will be given here.

The maximum power obtainable in the secondary circuit from one gap is about 40 to 50 watts.

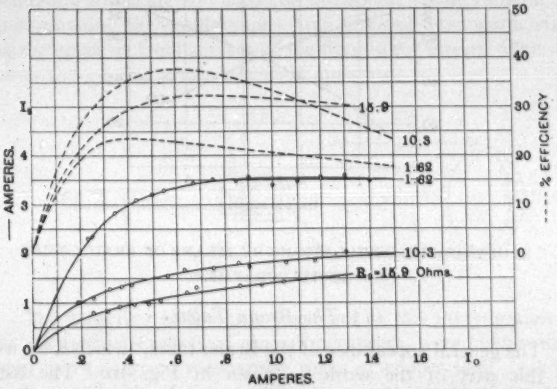
The efficiency is generally between 30 per cent. and 40 per cent., but may be somewhat higher. The maximum efficiency is generally obtained when the supply current is from .3 to .8 ampere.

The curves of Fig. 8 are typical and show the effect on the efficiency of changing the supply current, I_0. The secondary wave length was maintained constant at 100 metres. The full line curves show the variations in current in amperes in the secondary circuit for three values of secondary resistance, as the

main supply current, I_0, is varied from 0 to 1.5 amperes. The dotted curves give the efficiencies for the three curves, plotted to the right hand scale.

If greater power is required, gaps can profitably be operated in series. Two gaps work perfectly and three gaps well on 500 volts, with much increased power output. Four gaps were satisfactorily run on 1000 volts, but in general there is a slight sacrifice of regularity of operation as the number of gaps in series is increased.

FIG. 8.



Secondary current and efficiency curves with changing current, [I_0].

λ_2 = 100 metres.
$C_1 = 175 \times 10^{-6}$ μf.
$C_2 = 86 \times 10^{-6}$ μf.

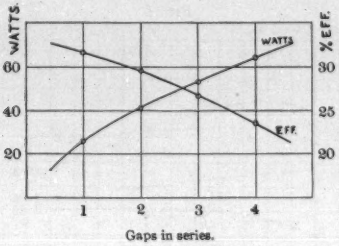
The amount of power obtained, when gaps are operated in series with a definite supply current, is not directly proportional to the number of gaps. When two gaps are operated in series, the power output is almost twice that from one gap. When more gaps are connected in series, the gain in power is much less, the greater the number of gaps the less the gain in power output.

The average voltage across one gap ranges from 100 to 200. As the number of gaps in series is increased, the current being constant, the voltage across the series is practically proportional to the number of gaps.

The efficiency of the system, when gaps are operated in series, decreases as the number of gaps is increased.

The curves of Fig. 9 give an idea of the result of increasing the number of gaps in series. The values of the efficiency and power may be somewhat misleading as the adjustments were not for conditions of maximum power and efficiency. The general shape of the curves, however, may prove of interest.

FIG. 9.



STUDY OF THE OSCILLATIONS BY MEANS OF BRAUN-TUBE OSCILLOGRAPHS.

(1) *The Braun Tubes.*

The general appearance of the Braun tubes,[3] which were used in this part of the work, is given in Fig. 10. The usual aluminum diaphragms were found unsuitable and were replaced by glass diaphragms having the shape of a truncated cone, the apertures being about .5 to .7 mm. in diameter.

Braun tubes making use of electrostatic deflection of the cathode beam were also used in parts of the experiment. They are essentially the same as those just described with the addition of the two electrostatic deflecting plates. These plates are about 8 by 2.5 cm. in dimensions, and are sealed inside the tubes about 2.5 cm. apart.

The tubes were operated on from 10,000 to 20,000 volts

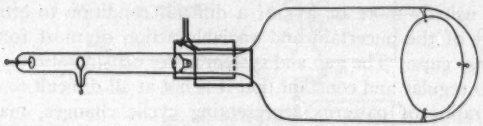
[3] F. Braun, *Wied. Ann.*, 60, 552 (1897); *Elektrot. Ztschr.*, 19, 204 (1898). Zenneck, *Ann. d. Physik.*, 9, 497 (1902).
J. M. Varley, *Phil. Mag.*, 3, 500 (1902).
Varley and Murdock, *Electrician* (London), 55, 335 (1905).

direct current, derived from Professor Trowbridge's 40,000-volt secondary battery. A large resistance, composed of tubes of running water, was placed in series with the tubes in order to control the current should the vacuum change.

The tubes were in connection with a Gaede mercury pump in order to maintain the pressure in the tubes at just the right value.

In order to eliminate the deflection of the beam by the earth's magnetic field, the tubes were mounted with their axes parallel to the earth's magnetic force, which mounting gave the tubes an inclination of about 70° with the horizontal. The camera, for photographing the oscillographs, was directed downward, viewing the upper or front surface of the fluorescent screen. Plate 1 *a*, shows the general arrangement of apparatus.

FIG. 10.



Braun tube and deflecting coil.

The deflecting coils which were used in this investigation for the magnetic deflection of the cathode beam, were composed of from two to sixteen rectangular turns of copper wire, .325 cm. in diameter, half of the turns being on either side of the tube. The turns were about 7 or 8 cm. in width, and from 10 to 12 cm. in length. A nearly uniform field within the coil is secured by making the width of the rectangular turns $\sqrt{2}$ times the distance between the planes of the two parts of the coil.

When using high frequencies, the difference in potential between two parts of the same coil, due to inductance, is sufficient to cause very large electrostatic deflections of the cathode beam. This disturbance is most effectually eliminated by surrounding the tube, inside the coil, by a split solenoid of fine insulated copper wire wound on a paper tube. This device completely shields the cathode beam from electrostatic disturbances, but allows the magnetic forces to pass undiminished.

When the Braun tube is used for alternating currents of commercial frequencies, or for phenomena taking place in a few

hundredths of a second, the velocity of the luminous spot over the screen is small enough to give a visible streak of light even if the phenomenon lasts for only one cycle.

When high frequency currents are used, however, the velocity of deflection of the cathode beam is so great that it is necessary that the luminous spot travel over the same path thousands of times a second in order that even a visible effect may be observed, and many more times if a photographic record is to be taken with a reasonable exposure.

It is then apparent that, if a sequence of instantaneous phenomena is to be delineated by causing the cathode beam to trace out a pattern on the fluorescent screen of the Braun tube, the cycle of events must repeat many hundreds of thousands of times a second, and with such regularity that the spot of light will, each cycle, travel over exactly the same path.

When using the Braun tube for studying electrical oscillations, this is usually more or less of a difficult condition to attain on account of the uncertain and variable action of most forms of discharge gaps. The gap and system under consideration is, however, so regular and constant that it is not at all difficult to obtain photographs of patterns representing cyclic changes, many of which recur three million times a second with practically no variation.

Plates 1–7 are a few of over fifteen dozen photographs taken representing various conditions, and give unmistakable evidence of the remarkable regularity and continuity of the oscillations of the *Cu-Al* gap. The photographs were taken on Seed's Gilt Edge No. 27 plates, and exposures of from 3 to 30 seconds were made. The figures are practically natural size.

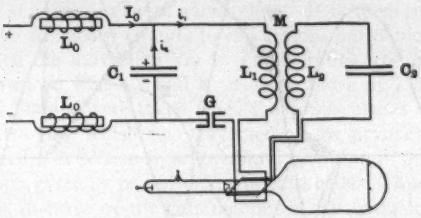
(2) *The Primary Wave.*

The observations for determining the shape and phase, with respect to the secondary oscillation, of the primary current rush were obtained by leading the primary and secondary currents each through a 4-turn deflecting coil about the Braun tube, the two coils making an angle of 90° with each other. The arrangement is diagrammatically shown in Fig. 11, where the letters have the before-mentioned significance. There is obtained on the fluorescent screen by this arrangement a perfectly definite and well defined pattern, which gives the corresponding instantaneous values of the primary and secondary currents. Plate 1 *c*,

is one of many photographs of such a pattern, taken with an exposure of about 15 to 30 seconds, and represents the conditions when adjustments are made for maximum energy in the secondary circuit.

Knowing, as will be adequately proved later, that the secondary oscillation is sinusoidal, the primary current, plotted to time, and its phase relation to the secondary current, can readily be derived from the patterns mentioned above. In *c* of Plate 1 the vertical distance d_1 to the primary loop above, from any point on the horizontal line distant d_2 from the centre or undeflected spot, gives the instantaneous primary current, i_1, and the simul-

FIG. 11.



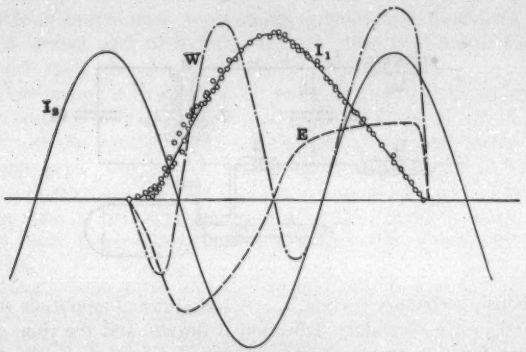
taneously secondary current, i_2. A sine curve of amplitude represented by the secondary deflection is drawn, and the time coördinate for any corresponding values of i_1 and i_2 is the time, obtained from the sine curve, at which the current coördinate is i_2. The direction of the spot of light is indicated by the arrows. The curve marked I_1, in Fig. 12, shows the development of two figures, both reduced to the same scale for better comparison. I_2, in the figure, is the secondary current. Seven such developments were made representing entirely different conditions, but in each case the phase of I_1 with respect to I_2 was the same as is shown in Fig. 12, and the shapes of the I_1 curves differed so slightly that, to save confusion, they are not reproduced.

Examination of the photograph and of the developments show, as has been stated, that there is *no* inverse current. Although the primary wave appears to have twice the period of the secondary oscillation, if the slope of the curve, or $\frac{di_2}{dt}$, which is proportional to the resulting induced electromotive force in the

secondary circuit, be plotted, a curve of the *same* period as I_2 is obtained. This e. m. f. curve is shown at E in Fig. 12.

If, now, the ordinates of the e. m. f. curve be multiplied by the corresponding values of the secondary current, a quantity proportional to the instantaneous rate at which energy is being transferred to the secondary is obtained, and if plotted, gives the curve marked W in Fig. 12. The portions of the curve below the axis of time are negative, and represent a return of energy to the primary circuit. The algebraic sum of the areas under the four loops is proportional to the total energy permanently deliv-

FIG. 12.



I_1.....Primary discharge wave.
I_2.....Secondary wave.
E.....Electromotive force due to I_1.
W.....Power delivered to secondary circuit.

ered to the secondary circuit in one cycle. It is apparent that very little energy is returned to the primary circuit, and that the second half of the primary loop gives the greater amount of energy to the secondary circuit, the first part of the primary discharge being more or less irregular on account of the sudden breaking down of the high initial gap resistance and the superposed higher harmonies resulting from the sudden shock to the system.

It has been stated that the primary current loops occur every two or more secondary oscillations. In this case the primary wave, considered as an intermittent function, can be analyzed

into harmonics. Such an analysis has been made for several values of I.C.F. One result only will be given here; namely, the development for an I.C.F. of 2.

$$e_2 = E\left[.43 \sin 2\pi\left(\frac{n}{2}\right)t + .50 \sin 2\pi nt + .26 \sin 2\pi\left(\frac{3n}{2}\right)t \right.$$
$$\left. -.061 \sin 2\pi\left(\frac{5n}{2}\right)t + .028 \sin 2\pi\left(\frac{7n}{2}\right)t - .017 \sin 2\pi\left(\frac{9n}{2}\right)t + \ldots \right]$$

A beautiful way of demonstrating the existence of the harmonics is by the following experiment. Two secondary circuits are arranged so that they can be excited by the same primary circuit. Each of the secondary circuits includes a deflecting coil about the Braun tube, these coils being so placed as to produce deflections at right angles to each other. It is then possible to tune the two secondary circuits to the various harmonics, and to obtain, when the harmonics are in simple ratios, the Lissajou's figures shown on Plates 1 and 2. Cuts *d* and *e* of Plate 1 and *a* and *b* of Plate 2 were taken when there was placed about the tube an extra coil, which was traversed by the primary current, and produced a deflection in a horizontal direction in addition to the deflection given by one of the secondary coils. This arrangement gives, in three of the cuts mentioned, an extra loop when the primary is active.

(3) *The Resistance of the Gap.*

The shape of the primary wave form, which has just been considered, is determined principally by the changes in resistance which take place in the gap. If there were no change in resistance, and the influence of the secondary current were negligible, the form of the primary current rush would be given by the familiar equation

$$i_1 = \frac{Q_0}{\sqrt{R_1^2C_1^2 - 4L_1C_1}}(e^{-\alpha t} - e^{-\beta t}),$$

where

$$\alpha = \frac{R_1C_1 + \sqrt{R_1^2C_1^2 - 4L_1C_1}}{2L_1C_1}$$

and

$$\beta = \frac{R_1C_1 - \sqrt{R_1^2C_1^2 - 4L_1C_1}}{2L_1C_1}.$$

Q_0 is the initial charge in the primary condenser C_1, and L_1 and R_1 are the inductance and resistance in the primary circuit. The curve, which represents this equation, is, as is well known, a rise and fall of current with respect to time, and is aperiodic or oscillatory according as R_1^2 is greater or less than $4L_1/C_1$. The critical resistance above which the discharge is non-oscillatory is, for the circuits which were used in this investigation, of the magnitude of 100 ohms. As will be seen later, the average resistance of the gap is so low compared to this quantity that the existence of no inverse current cannot be attributed solely to the aperiodic nature of a discharge through a high resistance. Moreover, if the average resistance were high enough to cause the discharge to be aperiodic, the end of the discharge would be asymtotic to the time axis, which is not the case.

The change of resistance of the gap can be obtained experimentally by use of a Braun tube provided with electrostatic deflecting plates. These electrostatic plates are connected directly across the gap, causing a deflection perpendicular to that caused by the total current through the gap. In this way a trace of the voltage-current characterstic curve is obtained from which can be derived the resistance corresponding to any current.

Cuts *a–e* of Plate 3 are photographs of *E–I* characteristic curves as above described. Cut *a* represents the conditions for a very long gap. The path of the spot of light, in tracing this figure, may be understood from the following. As the condenser charges there is no current through the gap, and hence no current deflection, but the potential of the condenser increases to a certain value determined by the breaking-down potential of the gap. This charging is represented in the photograph by a movement of the luminous spot from *A*, its undeflected position, to *B*, the potential at which the gap breaks down, which in magnitude, in this case, is equal to about 450 volts. The instant that the gap breaks down the potential drops, and the current through the gap increases giving the curve from *B* to *C*, roughly resembling a hyperbola. As the current decreases, represented by the line *CA* in the photograph, the potential remains practically zero, showing that after the gap has been once ionized the resistance remains low until the current becomes zero. The current does not increase in the negative direction for reasons previously given. During the passage of the primary current the capacity, C_1, has

been completely discharged and charged in the reverse direction so that, as soon as the current stops, the full potential of the reversed condenser is brought to bear across the gap. This is represented by the point D. Current is now, however, flowing into C_1 at a constant rate, causing the fluorescent spot to move along the voltage axis from D to B to begin a new cycle.

The same kind of diagram is shown in cuts *b* and *c* of Plate 3 for shorter gaps. It is evident, as would be expected, that as the gap is shortened, the E–I curve closes in toward the two axes.

It is also seen that with a very short gap the current increase is oscillatory. These oscillations are very rapid, having a wave length of the magnitude of four or five meters, and on account of the extremely high frequency, cause the large potential oscillations shown by the blurred space in cut *d* of Plate 3.

Cut *e* of Plate 3 is a photograph taken when, on account of the dryness of the hydrogen, practically nothing but a glow discharge could be obtained. The gap in this particular case was traversed by a high frequency current. The photograph is introduced only for the small curved point at the right hand end of the potential deflection, which is the characteristic of the glow discharge.

Cut *f* of Plate 3 was taken in the same manner as the pictures just described except for the addition of a secondary deflection coil parallel to the primary coil about the tube. In this way there is obtained a spreading out of the diagram, and a clearer view of the actual path of the luminescent spot. The helical path from right to left results from the secondary current oscillation, and superposed primary potential oscillations due to the influence of the secondary vibrations on the primary circuit, both occurring during the charging of the primary condenser. The abrupt end represents the point at which the gap breaks down and the spot moves very rapidly, at first, over the primary discharge loop.

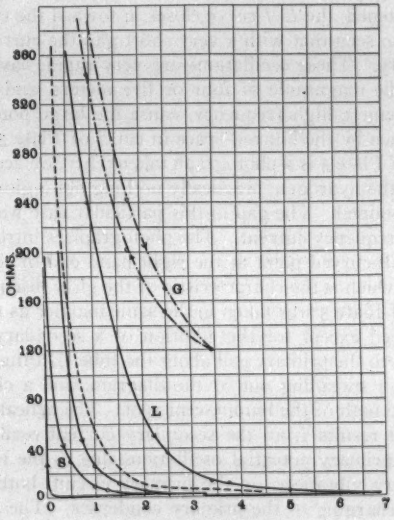
The change in resistance with changing current, derived from these E–I characteristics, gives curves of the general shape shown by the full line curves of Fig. 13. The curve marked L was derived from cut *a* of Plate 3, and represents the change in resistance of a very long gap. The other two full-line curves are for shorter gaps, and, in the extreme corner, is suggested the condition for decreasing current which completes the cyclic resistance changes.

The dotted curve of Fig. 13 is a resistance curve derived from the differential equations of the circuit by assuming an

approximate expression for the primary wave form. It agrees well in shape with the experimental curves (heavy lines).

The scales of the curves serve only to give an approximate idea of the magnitudes of the resistances at different currents, for the position of the curves depends upon the arc length and undoubtedly upon the period of discharge. It is worthy of note

FIG. 13.



Resistance curves of *Cu-Al* gap.

G ..... Glow discharge.
L ..... Discharge with very long gap.
S ..... Discharge with very short gap.
Dotted curve ..... calculated.

that the resistance at zero current is very high, thus admitting of a high initial charge in the primary condenser before the gap breaks down. The resistance curves are very steep, being much steeper than the corresponding curves for the Poulsen arc. It is, in part, this steepness which adapts the gap to the production of very high frequency oscillations. The very rapid reëstablish-

ment of the high resistance is also of primary importance in the action of the gap with high frequencies.

The upper dot-and-dash curve is for the curved point at the end of the potential deflection in cut *e* of Plate 3 just mentioned, and represents the conditions for glow discharge.

(4) *The Inverse Charge Frequency* (*I. C. F.*).

Reference has often been made to the I. C. F., the value of which, as was stated, depends upon the wave length of the secondary oscillation, the size of the primary condenser C_1, and the value of the supply current I_0. In order to show that the I. C. F. has, under most conditions, a perfectly definite value, and at the same time, to illustrate some other points concerning the system, the photographs of Plate 4 were taken.

The arrangement of circuits, for the figures under discussion, was as follows: Two parallel deflecting coils were placed about the Braun tube, and so situated as to deviate the cathode beam in a direction perpendicular to the electrostatic deflection. One of these coils was connected in the primary circuit and the other in the secondary circuit. The electrostatic deflecting plates were connected to the terminals of the primary condenser C_1.

The oscillograms of Plate 4 represent, therefore, the sum of the primary and secondary currents by deflections in the vertical direction, and the potential of C_1, by deflections in the horizontal direction. In all of the cuts the lower portion results from the secondary oscillation during the charging of C_1, when the gap current is zero.

The explanation of cut *b* will serve for all of the pictures of Plate 4. At point A the condenser C_1 is charged to a potential sufficient to jump across the gap. When the primary discharge begins, the spot of light moves very rapidly at first over the loop ABC. This discharge starts or maintains the secondary oscillation, so that the vertical deflection is due to the primary current plus the simultaneous secondary current. During the discharge the potential of the primary condenser falls and increases in the opposite direction, so that, at the end of the discharge, represented at C, the condenser potential is reversed. At point C the primary discharge is completed. The rest of the diagram from C to A is due to the secondary oscillation, which causes the vertical deflection, and the uniformly changing poten-

tial of the primary condenser while charging, which causes the horizontal deflection from *C* to *A*.

The number of secondary oscillations taking place during one primary cycle, and which has been called the I. C. F., is clearly shown by the photographs. In the case of cut *b*, the secondary completes one period during the primary discharge, and three complete secondary periods during charging from *C* to *A*, so that the I. C. F. is 4.

The instant at which the primary discharge begins and ends with reference to the secondary wave, is shown to be the same as was derived in the section on the primary wave. The high harmonic oscillations in the primary which occur, as has been mentioned, after the high resistance of the gap is broken down, are apparent in the beaded appearance of the upper loops of the oscillograms.

In cuts *a–e* of Plate 4 the spot travelled over the patterns in an anti-clockwise direction. The I. C. F.'s are respectively 3, 4, and 6. In cuts *a* and *b* the undeflected position of the spot is shown, and the relative magnitudes of the direct and inverse potentials of the primary condenser can be noted.

The beats, shown in cuts *c–f* of Plate 4, are due to the interference of two oscillations in a doubly-periodic secondary system employed in this case. The second-secondary oscillation is due to the vibration of an helix, a few turns of which were included in the secondary circuit. The luminous spot in cut *d* travelled in a clockwise direction.

(5) *Resistance Damping.*

In order to obtain an oscillogram of a variable which is a function of time, it is necessary to use some device which will give a uniform time axis to the figure. For instance, if it is desired to obtain an oscillograph of the commercial alternating current, one passes the current through the deflecting coil about the Braun tube. There appears on the screen a straight line, which results from the to-and-fro movements of the luminous spot over the same straight path. In order to see the current wave developed with respect to time, it is necessary to observe the line deflection in a revolving mirror, its axis being parallel to the line deflection. If a photograph is to be taken, it is further necessary to drive the mirror by some synchronous device so that

the image of the developed figure may be stationary on the photographic plate for a time sufficient to make the exposure. This synchronizing device is not difficult to arrange when using commercial alternating currents, but when it is desired to take an oscillogram of a high frequency current or condenser discharge, it is usually impossible to make the necessary synchronization. When using high frequency currents, the velocity of the spot of light on the fluorescent screen is so great that, in order to obtain a photograph, it is necessary that the cycle of changes, as shown by the pattern on the screen, be repeated many hundred thousand times with such regularity and certainty that the image is always in exactly the same position. The requirements of both the acting system and the synchronizing device are very rigid.

The development of the time axis can be most effectually accomplished, with the system under discussion, by the very simple connection which was used in the last section. The electrostatic plates, which cause a deflection perpendicular to the current coils, are connected to the terminals of the primary condenser C_1. During the interval between primary discharges, when the primary condenser is charging, the primary current is zero, and the main or charging current is almost perfectly constant on account of the large inductances in the mains. This uniform charging causes a uniform increase in potential of the condenser C_1, and hence a uniformly developed time axis on the fluorescent screen. The oscillations of the secondary, or any effect started by the primary discharge, is thereby developed, as is shown by the lower portions of the cuts of Plate 4.

This arrangement for the development of current or potential deflection with respect to time is of the greatest use in many ways. Its application will be illustrated here by showing the damping curves with oscillations of a frequency of two million or more per second.

Cuts *a* and *b* of Plate 5 represent the damping of the secondary oscillations due to the addition of resistance in the secondary circuit. The primary capacity and supply current were so adjusted as to give large values of the I. C. F. in order that as many secondary oscillations as possible might appear in the damped oscillation trains shown. The adjustments for the pictures of Plate 5 were so made that each oscillation train is just completed before the beginning of the next. The trains, therefore, succeed

each other with no intervals of rest. By adjustments of the supply current or primary capacity it is possible to lengthen or shorten the interval between the primary discharges, and by varying the resistance in the secondary circuit the number of oscillations in one train or the damping can be varied at will. The damping is evidently exponential in fulfilment of the familiar theory.

Cuts *c–f* of Plate **5** and cut *a* of Plate **6** are the results of adding to the arrangement of circuits just considered a second secondary circuit, excited by the primary discharge. There results, therefore, a doubly-periodic secondary system having two secondary circuits inductively coupled together. The doubly-periodic secondary oscillation gives the beats and curious figures shown. Cuts *c* and *d* are due to the addition of two oscillations differing widely in frequency. As will be seen from the description of the figures, the second oscillation is in one case over twice and in the other case almost three times the frequency of the main secondary oscillation.

Cut *a* of Plate **6** shows beats taken with almost undamped oscillations. The wave lengths are not recorded, but they were probably of the magnitude of 100 meters.

(6) *Damping in a Circuit Containing a Spark Gap.*

When the dissipation of energy in an oscillatory circuit is proportional to the square of the current, as is the case in a constant resistance, the damping is exponential. If, however, the resistance is a function of the current the energy dissipation is no longer proportional to the square of the current, and the damping no longer exponential. For instance, the resistance of a spark gap or arc is a function of the current, the resistance being greater the smaller the current through the gap.

Richarz and Ziegler[4] in 1900 observed, in a revolving mirror, the straight line deflection which is produced in a Braun tube when a condenser is rapidly discharged across a spark gap and through the deflecting coil. The frequency of the oscillations was very low. On account of the impossibility of taking a photograph, we have only their description of the phenomenon as seen in the revolving mirror. In appearance the figure resembled the backbone of a fish, or, in other words, a long straight line,

[4] F. Richarz u. W. Ziegler, *Ann. d. Phys.*, 1, 468 (1900).

due to the undeflected spot, and at intervals along the line, pairs of equally inclined short straight lines, as one would indicate an arrow point. The short lines were due to the more intense maximum deflections during a train of oscillations, the separate oscillations being entirely undiscernible. The results showed that the damping due to a spark gap is not exponential but approximately linear.

Zenneck,[5] in 1904, obtained further experimental proof of the approximately linear damping due to a spark gap. He photographed the line deflection, and by a process of projection from the several brighter spots, due to the decreasing amplitudes of the oscillations, derived the damping curves. Frequencies up to 1800 per second were used by him.

Heydweiller,[6] in 1906, showed that the results obtained by the above-mentioned experimenters can be deduced theoretically. Heydweiller assumes, in deducing the linear damping, that the gap has a characteristic expressible in the form

$$e = a + \frac{b}{i}$$

where e and i are the voltage across and current through the gap, respectively, and a and b are constants. He further assumes that b is negligible, which reduces the conditions to the assumption of a constant voltage across the gap. Solving the differential equation for the discharge of a condenser across a constant-potential gap, he obtained rectilinear damping.

If a discharge gap be substituted for the secondary resistance in the arrangement of circuits which was used in the last section for obtaining plain resistance damping, very clear oscillograms can be obtained of the oscillation trains when the damping is caused by a gap. Although the inherent irregularity of some metallic gaps, when used in the secondary circuit, causes some irregularity of the oscillographs, yet good photographic records can be obtained, as is shown by the cuts of Plates 6 and 7. In order to obtain a potential sufficient to maintain the discharge across the secondary gap, it was necessary to use a large primary condenser and supply current, and to make the ratio, $\frac{n_2}{n_1}$, of the secondary to primary turns on the helix large.

[5] J. Zenneck, *Ann. d. Phys.*, 13, 822 (1904).
[6] R. Heydweiller, *Ann. d. Physik.*, 19, 646 (1906).

Cuts *b* and *c* of Plate 6 show two of the pictures first taken, and illustrate well the linear damping. The gap length was very short; the terminals were of aluminum.

Further investigation showed that the oscillation train took on entirely different aspects according as the discharge could be classed as a *pure arc,* or a *spark discharge.* When the discharge is a pure arc, the separate oscillations are regular and practically sinusoidal, and the damping is still linear. If the discharge is classed as a spark discharge, although the damping is linear, the separate oscillation loops are distorted as will appear presently.

Cut *d* of Plate 6 represents the condition when the discharge terminals of the secondary gap are carbon. The discharge was quiet and very brilliant, resembling, as indeed it was, the pure carbon arc operating, however, at a frequency of 5.7×10^5 oscillations per second.

Cut *e* of Plate 6 gives the appearance of the oscillogram when the terminals are of aluminum in air. The discharge in this case, as well as for cuts *b* and *c,* was probably a pure arc due to the carbon and other impurities in the aluminum. In appearance, the discharge was brilliant and similar to the carbon arc.

Magnesium terminals usually give the pure-arc discharge-form of damping curve, due probably to the large amount of magnesium vapor present in the discharge, or possibly to the burning of the magnesium into the oxide.

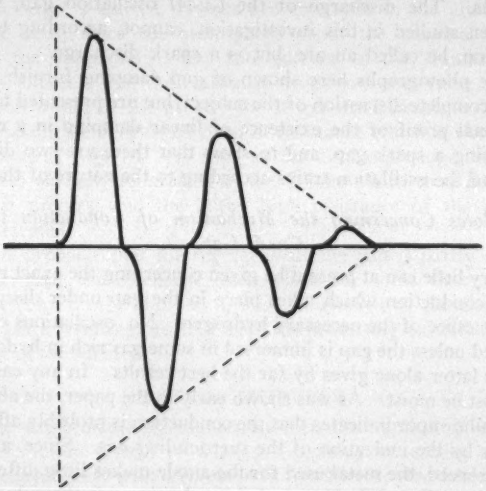
Cut *f* of Plate 6 and the pictures of Plate 7 represent the appearance of the *spark-discharge* oscillograms. When the temperature of the discharge is kept low, the conductivity of the gap is not maintained over the interval of zero current by the presence of incandescent metallic or carbon vapor, and the high resistance of the gap is partially established at each crossing of the axis by the current curve. This necessitates a reionization of the gas at the beginning of each current loop, or the breaking down of a possible oxide film, thereby distorting the wave in the neighborhood of the axis, as is shown by the figures.

The general form of the curve for spark damping, which is indicated in the photographs, was at times momentarily clearly outlined on the fluorescent screen and is shown by the drawing of Fig. 14. Apparently, in some of the photographs, the loops begin, in point of time, before the ending of the previous loop. This apparent paradox is due to the slight shift in the time axis

resulting from the reaction of the strong secondary discharges upon the potential of the primary condenser.

The oscillogram photographs of spark damping here shown were taken for aluminum terminals because of the greater regularity of the discharge between terminals of that metal. Many other metals were tried, such as copper, cadmium, zinc, etc., and in practically every case in which the discharge was a spark discharge, the oscillations took the same form as is shown in Fig. 14.

FIG. 14.



Form of spark-gap damping curve.

When one of the terminals is carbon or magnesium, the current loops on one side of the time axis are of the pure-arc form, while those on the other side are of the spark-discharge form.

If the terminals are dissimilar, there is usually evidence of a rectifying effect. Particularly is this so if one terminal is of aluminum and the other of copper or iron. Cut *d* of Plate 7 shows this rectification.

The effect of hydrogen on the discharge is indicated by cuts *e*

and *f* of Plate 7, which were taken under the same conditions except for the H surrounding the gap terminals in the case of cut *f*. The hydrogen serves, in this case, principally to ensure a spark rather than an arc discharge, and probably increases the damping.

The outward appearance of the discharge is in no way an indication as to whether the oscillogram takes the arc or spark form. The form of the oscillogram serves conveniently to differentiate between the pure-arc and the spark discharges, when the terms arc and spark are applied to discharges operating on alternating currents. The discharge of the *Cu-Al* oscillation gap, which has been studied in this investigation, cannot, according to this definition, be called an arc, but is a spark discharge.

The photographs here shown of gap damping furnish in no way a complete discussion of the subject, but are presented to give additional proof of the existence of linear damping in a circuit containing a spark gap, and to show that there are two distinct forms of the oscillation trains according to the nature of the gap.

(7) *Notes Concerning the Mechanism of Conduction in the Cu-Al Gap.*

Very little can at present be given concerning the exact nature of the conduction which takes place in the gap under discussion and the office of the necessary hydrogen. No oscillations can be obtained unless the gap is immersed in some gas rich in hydrogen, but the latter alone gives by far the best results. In any case the gas must be moist. As was shown early in the paper, the absence of metallic vapor indicates that the conduction is probably affected entirely by the ionization of the surrounding gas. Since, as was also observed, the metal used for the anode makes little difference in the operation of the gap, and since aluminum is the only metal which works at all well as cathode, it is safe to say that it is the aluminum cathode, working in conjunction with the hydrogen, which gives the characteristic properties of the oscillation gap which has been partially studied in the foregoing pages. It might be mentioned here that magnesium acts to some extent as cathode, but, on account of its low vaporizing point, works very irregularly and unsatisfactorily. The discharge, in this case, is intensely green, showing vaporization.

The fact that moisture in the hydrogen is necessary indicates

that an oxidation of the aluminum plays some part in the operation. The necessity of an hydrogen atmosphere leads one to believe that perhaps a reduction of the ever-present aluminum oxide film at some time during the cycle may take place, there possibly being a cyclic change of oxidation and reduction of the aluminum determined by the temperature at various instants during one primary discharge. For instance, it may be that some action such as follows takes place. At the beginning of the discharge, the thin oxide film makes necessary a high breaking-down potential in order to start a discharge. As soon, however, as the discharge is started, H ions are conveyed to the aluminum cathode, and, since the atmosphere about the terminal is H, reduce the oxide film. The free surface of the aluminum is thereby exposed, and the resistance drops to a low value. This reduction would be the greater the larger the current, and there would result the very rapid drop in resistance which is shown in the curves of Fig. 16. As soon as the discharge stops, the aluminum is partially reoxidized by the O ions which were freed by the first process, and the initial high resistance of the gap is re-established.

It is probable that the regularity of the gap is partly due to the fact that the discharge takes place for some time at one definite point on the aluminum, this confinement of the discharge to one place resulting possibly from the protecting oxide film over the rest of the surface.

WIRELESS TELEPHONY.

The experiments in connection with the application of this new oscillation system to wireless telephony have been carried on in conjunction with Professor G. W. Pierce, who has offered many valuable suggestions and done a great deal for the development of this application of the system.

A detailed description of the experiments which have been in progress for over a year cannot here be given; they will be the subject of a later article. A brief description of the method of operation, with some general statements concerning results, may, however, be of interest.

First, what are the essentials of a practical system of wireless telephony? In an ideal system of any form of telephony, the only audible effects at the receiving station should be the vibrations of

the telephone diaphragm synchronous with and proportional to the sound vibrations which are impressed at the transmitting station. This is quite successfully accomplished in the ordinary line telephony in the familiar manner. An electric current is the transmitting agent, and a sound is heard in the receiver *only* when this current is modified or varied. In wireless telephony transmission is obtained by means of electromagnetic-waves, and there should be no appreciable sound at the receiving station except when these waves are modified in some manner, as by the human voice. It is clear that this necessitates the emission, by the transmitter, of a perfectly steady, continuous stream of electromagnetic waves, of a frequency above the limit of audibility (about 35,000 per second). If the waves are not continuous, the train frequency must be above this limit. These waves must be capable of being modified by a telephone transmitter in such a manner that the envelope of the wave train, as it changes in amplitude, is the wave form of the sound vibrations which are impressed upon the transmitter diaphragm. The frequency of the waves should be high enough for efficient electric-wave transmission, or from 300,000 to 1,000,000 oscillations per second. Consequently, during one sound vibration there would be several hundred electrical vibrations.

In addition to the requirements stated above, the system, in order to be of practical value, should emit efficiently an electric wave of unvarying length. And, still more important, from a practical point of view, the system should be simple, reliable, and capable of being easily operated without the necessity of continual adjustment.

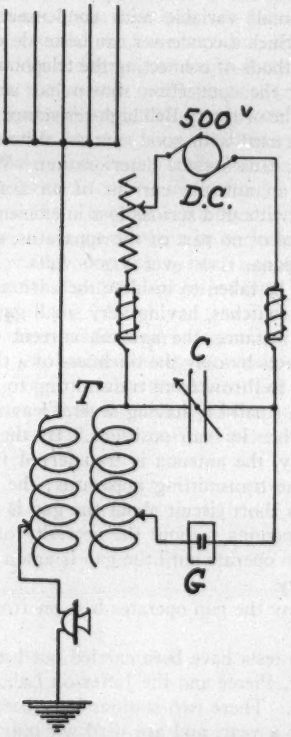
High-frequency alternators and the Poulsen arc, with its modifications, have been used for wireless telephony during the last few years with some success. The greatest faults of the alternator system are its great expense and its inefficiency. The Poulsen-arc [7] system is complicated, and requires continual adjustment, which makes it difficult to operate. Further, it emits waves which vary in length as the arc length and supply current change, an inherent characteristic of the system.

The connections for the transmitting station, which is now to be described, are shown in Fig. 15. The connections of the

[7] V. Poulsen, British Patent Specifications, 15,599 of 1903.

supply and primary circuits, as may be seen in the figure, are identical with the corresponding connections described earlier in the paper. *G* represents the gap, and *C* is a small variable air or oil condenser. *T* is a closely-coupled, and preferably variable,

FIG. 15.



oscillation transformer. The telephone transmitter is shown connected in the ground lead. The hot-wire ammeter in the antenna, and the throw-over switch to change from sending to receiving, are not shown.

A variable condenser of the semi-circular plate type, designed as an air condenser, was filled with castor oil (with dielectric constant 4.5) and used with one set of apparatus as the primary condenser. Its maximum capacity was about .009 μ f. The oil was used not to increase the dielectric strength, for that is unnecessary on account of the low potentials, but to increase the capacity. A small variable mica condenser was also used in another case. Such a condenser can be made very small.

Various methods of connecting the telephone transmitter have been tried, but the connection shown has so far proved most satisfactory. The ordinary Bell high-resistance microphone transmitter has been used with good success, although the large overload in current causes some deterioration. We have, however, used them on an antenna current of an ampere or more for several months without a serious loss in efficiency.

The potential of no part of the apparatus, except possibly the top of the antenna, rises over 1,000 volts. No great caution, therefore, need be taken to insulate the various parts of the system, and small switches, having very small gaps when open, can be used. For instance, the antenna current can be broken by separating contacts by only the thickness of a thin piece of paper.

The switch, to throw from transmitting to receiving and *vice versa*, may be a small key having several leaves which make certain contacts when in both positions. By the one operation of pressing the key, the antenna is transferred from the receiving apparatus to the transmitting apparatus; the detector is short-circuited; and a short circuit about the gap is broken. The gap immediately functions without the necessity of any adjustment, and continues to operate until the gap is again short-circuited by releasing the key.

For telephony the gap operates best on from .2 to .5 ampere direct current.

Most of the tests have been carried out between a station at the home of Dr. Pierce and the Jefferson Laboratory, a distance of about a mile. These two stations have been permanently installed for over a year, and are used not only for experimental purposes, but as a means of easy and practical communication with the laboratory.

When the transmitting station is properly tuned, there is practically no sound at the receiving station other than the voice.

The slight hum or hiss which is present to a more or less degree, according to the adjustments, is usually not at all objectionable and may be tuned out. The articulation is very good, and communication is easily maintained between the two stations for hours at a time with the loss of hardly a word, and, what is practically of great importance, without the slightest adjustment.

No definite statement can now be given as to the distance to which it is possible to talk. Our conversation has been reported as being understood at a distance of about forty miles, and it is very probable that the speech could be heard at a somewhat greater distance, even while employing only one gap.

Two gaps operated in series give much more power, but no experiments have been made to determine the maximum distance over which communication can be maintained.

By interposing into the antenna circuit a small battery buzzer, the continuous radiation of waves can be periodically interrupted and a very satisfactory telegraph system is obtained, which is difficult to distinguish from a high-frequency alternator or a rotating gap system.

No attempt has been made to give a complete discussion of the application of this oscillation system to wireless telephony, but enough has been given to enable one to see that the system does possess, to a greater extent than do the other systems, many of the essentials of a practical system of wireless telephony.

PLATE 1.

Mounting of Braun Tube.

a.

b.

Spectrum of Gap
with
Aluminum Comparison.
Spectrum.

c.

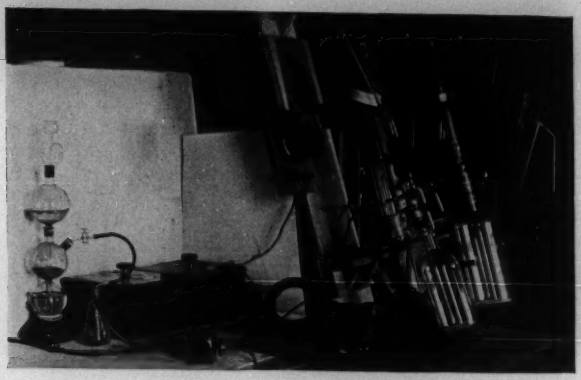
$I_0 = .73$ ampere.
$\lambda_2 = 110$ meters.
I. C F. = 5.

d.

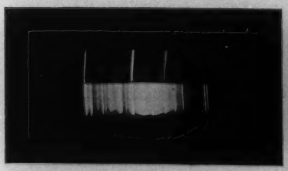
$\lambda_1 = 118$ meters.
$\lambda_1 = 236$ meters.
Ratio = 1:2.
I. C. F. = 4.

e.

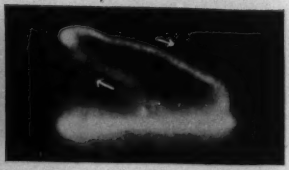
$\lambda_2 = 76$ meters.
$\lambda_2 = 114$ meters.
Ratio = 2:3.
I. C. F. = 4.



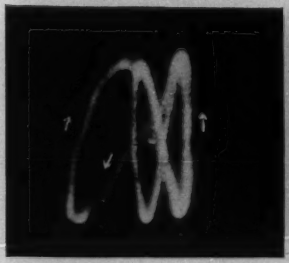
a.



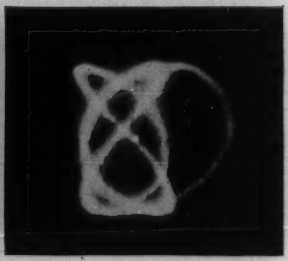
b



c



d



e

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PLATE 2.

LISSAJOU'S FIGURES.

a.

$\lambda_2 = 80$ meters.
$\lambda_3 = 120$ meters.
Ratio 2:3.
I. C. F. = 6.
$I_0 = .65$ ampere.

b.

$\lambda_2 = 158$ meters.
$\lambda_3 = 474$ meters.
Ratio 1:3.
I. C. F. = 3.
$I_0 = 1$ ampere.

c.

$\lambda_2 = 173$ meters.
$\lambda_3 = 231$ meters.
Ratio 3:4.

d.

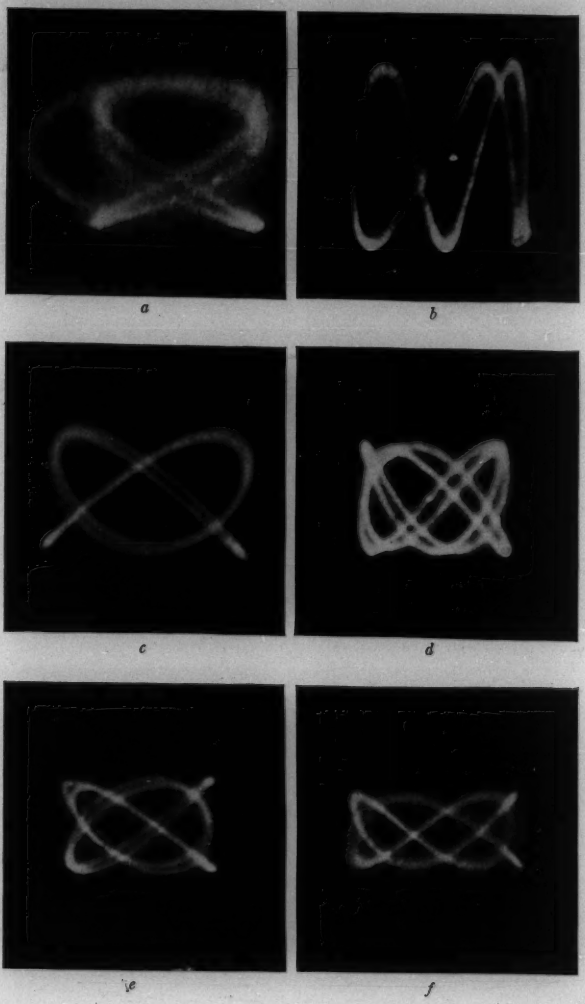
$\lambda_2 = 180$ meters.
$\lambda_3 = 300$ meters.
Ratio 3:5.

e

$\lambda_2 = 200$ meters.
$\lambda_3 = 250$ meters.
Ratio 4:5.

f.

$\lambda_2 = 180$ meters.
$\lambda_3 = 315$ meters.
Ratio 4:7.



a *b*

c *d*

e *f*

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PLATE 3.

E—I CHARACTERISTICS.

a.—Very Long Gap.

$I_0 = .55$ ampere.
1 cm. = 5.0 amperes (vertical).
2 cm. = 280 volts (horizontal).

b.—Long Gap.

$I_0 = 1.0$ ampere.
1 cm. = 4.75 amperes (vertical).
1 cm. = 280 volts (horizontal).

c.—Short Gap.

$I_0 = .54$ ampere.
1 cm. = 1.45 amperes (vertical).
1 cm. = 260 volts (horizontal).

d.—Very Short Gap.

$I_0 = 1.5$ amperes.
1 cm. = 4.75 amperes (vertical).
1 cm. = 280 volts (horizontal).

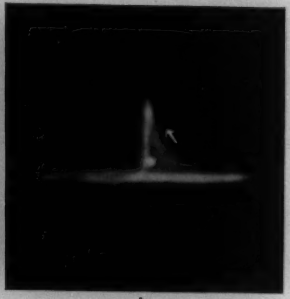
e.

Cu-Al gap operating on oscillatory current. Characteristic of Glow Discharge shown at the end of the potential deflection.

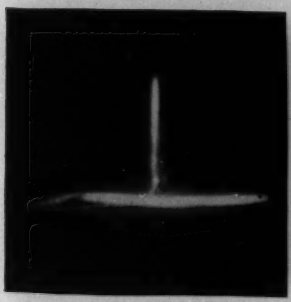
f.

$\lambda_2 = 268$ meters.
$I_0 = .5$ ampere.

a



b



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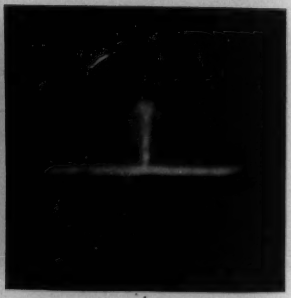

d

e

f

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PLATE 4.

a.

$\lambda_2 = 185$ meters.
$I_0 = .85$ ampere.
$C_1 = 178 \times 10^{-5}$ $\mu.f.$
I. C. F. = 3.

b.

$I_0 = .68$ ampere.
$C_1 = 110 \times 10^{-5}$ $\mu.f.$
I. C. F. = 4.

c.

$\lambda_2 = 180$ meters.
$I_0 = .32$ ampere.
I. C. F. = 6.

d.

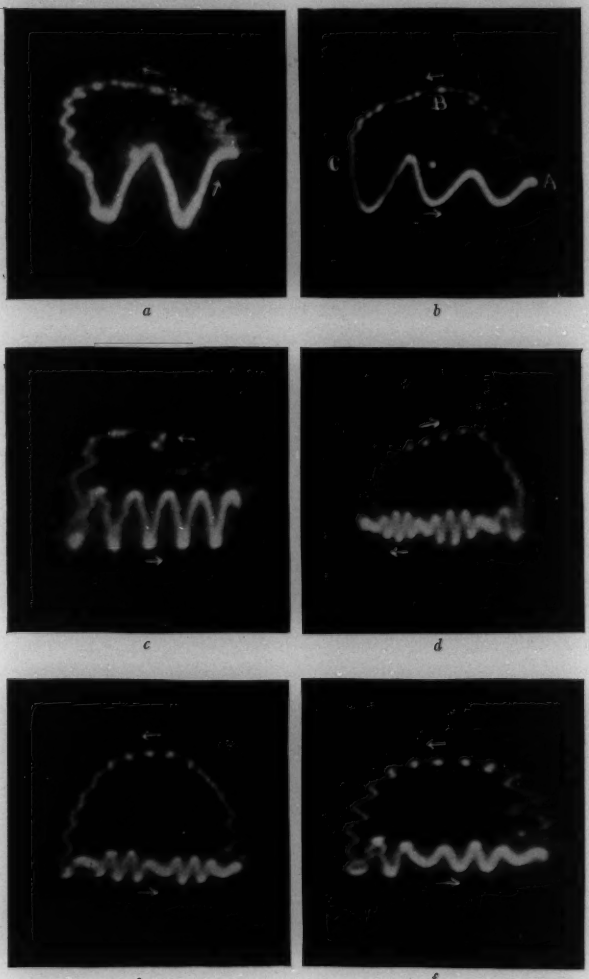
$\lambda_2 = 78$ meters.
$I_0 = .63$ ampere.
I. C. F = 9.

e.

$\lambda_2 = 88$ meters.
$I_0 = .4$ ampere.
$C_1 = 170 \times 10^{-5}$ $\mu.f.$
I. C. F. = 11.

f.

$\lambda_2 = 65$ meters.
$I_0 = .5$ ampere.
I. C. F. = 7.



a *b*

c *d*

e *f*

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PLATE 5.

Resistance Damping and Beats.

a.

$R_2 = 5.9$ ohms.
$\lambda_2 = 112$ meters.
$I_0 = .35$ ampere.
$C_1 = 150 \times 10^{-3}$ $\mu.f.$
$I.\ C.\ F. = 12.$

b.

$\lambda_2 = 400$ meters.

c.

$\lambda' = 154$ meters.
$\lambda = 325$ meters.

d.

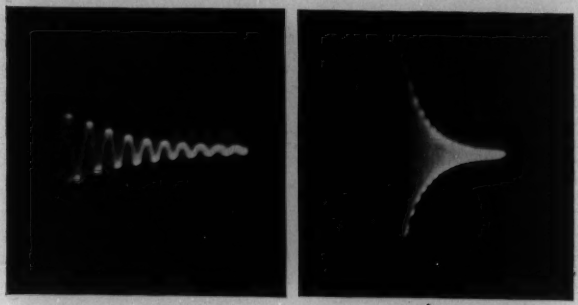
$I_0 = .4$ ampere.
$\lambda' = 140$ meters.
$\lambda = 390$ meters.
$R_2 = 6$ ohms.

e.

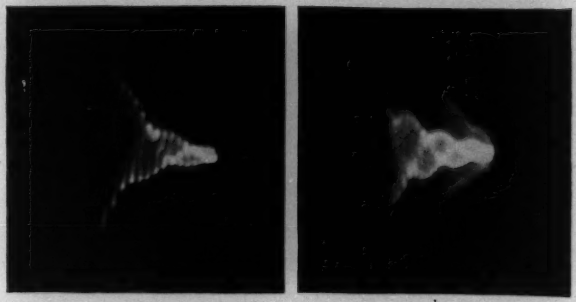
$\lambda = 370$ meters.
$\lambda' = 290$ meters.

f.

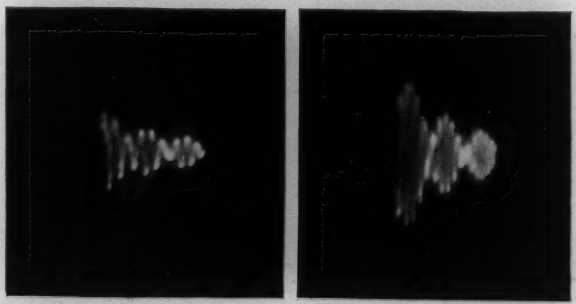
$\lambda = 215$ meters.
$\lambda' = 255$ meters.



a *b*



c *d*



e *f*

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PLATE 6.

GAP DAMPING OSCILLOGRAPHS.

a.

Beats.

b.—Al-Al in H.

$\lambda = 520$ meters.
$I_0 = 1.2$ amperes.

c.—Al-Al in Air.

$\lambda = 525$ meters.
$I_0 = 1.2$ amperes.

d.—Carbon-Carbon in Air.

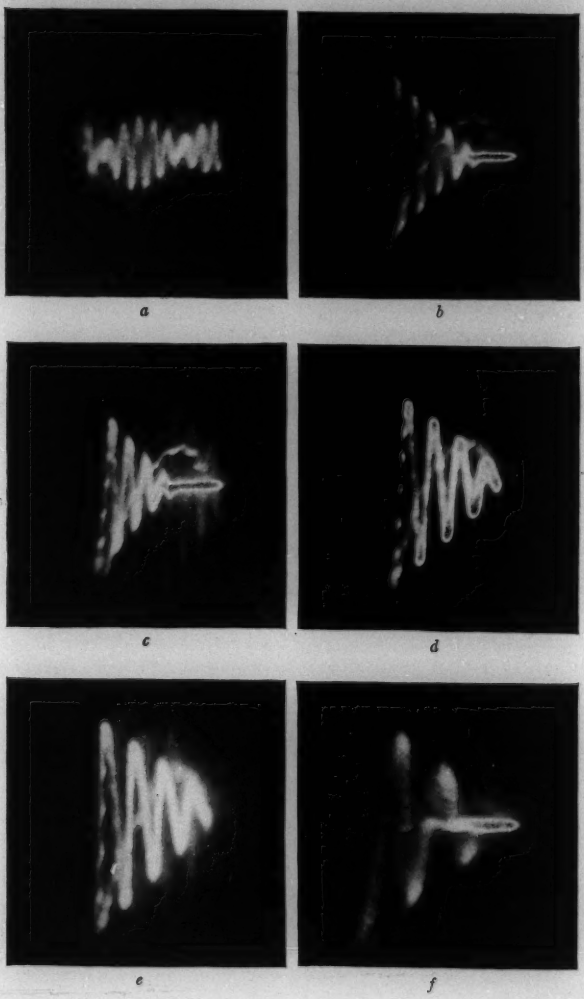
$\lambda = 525$ meters.
$I_0 = 1.4$ amperes.

e.—Al-Al in Air.

$\lambda = 575$ meters.
$I_0 = 1.5$ amperes.
Water cooled.

f.—Al-Al in H.

$\lambda = 575$ meters.
$I_0 = 1.9$ amperes.
Water cooled.



a *b*

c *d*

e *f*

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PLATE 7.

Gap Damping.

a.—Al-Al in Air.

$\lambda = 525$ meters.
Water cooled.

b.—Al-Al in Air.

$\lambda = 525$ meters.
Water cooled.

c.—Al-Al in H.

$\lambda = 525$ meters.
Water cooled.

d.—Cu-Al in H.

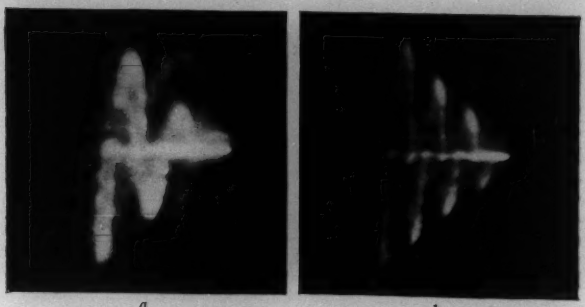
Shows rectification.

e.—Al-Al Arc in Air.

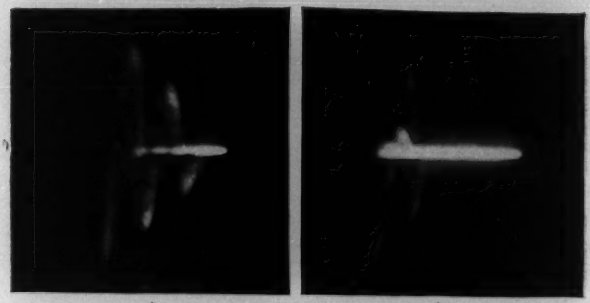
$\lambda = 525$ meters.
$I_3 = 1.3$ amperes.

f.

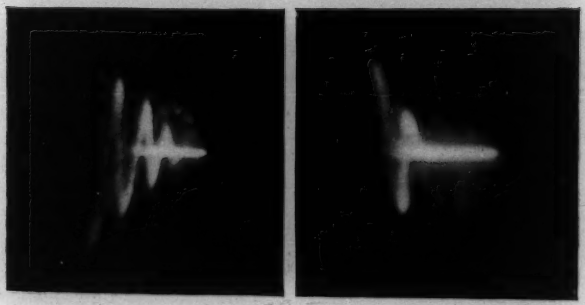
Same as Figure 5, except hyd-ogen instead of air surrounded gap.



a *b*



c *d*



e *f*

The Electrical Theory of Dyeing. W. HARRISON. (*J. Soc. Dyers and Col.*, xxvii, 279.)—Various dyeing phenomena have been investigated. It was found that, generally speaking, the effect of different salts and acids on the contact potential difference between cotton and water corresponds closely with the effect of these salts and acids on the amount of absorption by the cotton fibre of dyestuffs or mordants which are negatively charged in water. Moreover, if cotton is treated with various reagents, such as caustic soda and nitric acid, under different conditions and is subsequently dyed, the increase in the absorption of dyestuff runs parallel with the decrease in contact differences. The absorption and fixation of direct dyestuffs is explained as follows: The color ions of direct dyestuffs are negatively charged; the metallic ions positively. The cotton is negatively and the water in immediate contact with it is positively charged. The fibre, therefore, repels the color ions but attracts the metallic ions, and, by absorbing them, reduces its own negative charge. Simultaneously the negative charge of the color ions is reduced by the positive ions in the water next to the fibre. The repulsion of the fibre for the dyestuff being thus neutralized, the color ions are able to approach and to be absorbed by the fibre and again increase its negative charge. The process is repeated until the dilution becomes too great. The actual fixation as distinguished from the absorption of the dyestuff is attributed to the precipitating action of the positive hydrogen ions set free by the fibre on the color ions. Since acid dyestuffs are not precipitated by dilute acids, they are not fixed under these conditions. The influence of the size of the dyestuff particles and the size of the pores of the fibre on the course of the dyeing process is also considered, and a large number of experimental results is recorded.

Developments in Steam Generation. H. G. STOTT. (*Elect. Rly. Journal*, xxxviii, 781.)—In American practice the use of measuring instruments in the boiler room has proved it possible to make the boiler conform more closely to the load curve than formerly. The Venturi meter for measuring the feed to the individual boiler; the Pitot tube in the steam pipe for giving a general indication of the relative amount of work done in different boilers; and a coal-measuring instrument in the chute or down-take coal pipe, have been used along with forced combustion, and the records of one-minute indications of steam and water-flow meters have been studied to show the variations in power due to variations in load. To meet these variations it is recommended that the boiler room should be designed for maximum operating conditions and economy at average load, and to sacrifice slight economy at light loads by working only one of a pair of grates to each boiler, the other being banked; or to employ the auxiliary use of liquid fuel; or to have grates capable of working with natural draught up to a given power and thereafter with forced draught.

RECENT ADVANCES IN THE ART OF BATTLESHIP DESIGN.[1]

BY

NAVAL CONSTRUCTOR D. W. TAYLOR, U. S. N.

In October, 1905, Great Britain laid the keel of a battleship materially larger than any before constructed and differing much from its immediate predecessors, notably in the fact that the heavy turret guns, instead of comprising two calibres, were all of the heaviest calibre—12 inches—and there was no intermediate battery of 6-inch calibre, the only calibre carried being 12 inches in the main battery and 3 inches in the secondary battery or torpedo defense battery. This vessel, named the Dreadnought, being constructed with unprecedented rapidity and under circumstances of unusual and, for Great Britain, unprecedented secrecy, was, largely for this reason, the best advertised ship in the world. It has been the fashion since to call large battleships Dreadnoughts, though in England, where the fashion originated, the expression super-Dreadnought is much used now, and doubtless we shall soon hear of super-super-Dreadnoughts.

While the Dreadnought herself has been thrown in the shade by the later vessels, some of which are more than fifty per cent. larger, she ushered in an era of world-wide competition in battleship building and rapid increase of size and power of individual ships.

Table I below shows the effective battleship tonnage on January 1, 1912, of the eight leading naval powers, divided between completed battleships of the pre-Dreadnought type and vessels of the Dreadnought type, built and building. For the purpose of this classification vessels having a main battery of all big guns, 11 inches or more in calibre, are classed as of the Dreadnought type. None of the eight nations of Table I is building battleships of any other type. Vessels over twenty years old are not included, so Table I shows approximately the battleship tonnage completed or laid down from 1891 to about 1906 as compared with that completed or laid down from about 1906.

[1] Presented at the stated meeting held Wednesday, February 21, 1912.

TABLE I.

Effective Battleship Tonnage.

Nations.	Pre-Dreadnought type built. Tons of displacement.	Dreadnought type built and building. Tons of displacement.
Great Britain	617,500	483,350
Germany	252,712	359,120
United States	334,146	221,650
France	286,005	92,368
Japan	191,698	41,600
Russia	122,250	158,000
Italy	97,500	85,620
Austria	74,613	80,000

Table I brings out clearly the world-wide "speeding up" in battleship building of the last few years. The figures for Great Britain and Germany make it clear why some people in Great Britain consider that country to have made a colossal blunder when she forced the pace by building a new and more powerful type of battleship. The result, of course, is to relatively reduce in value earlier battleships, as to which we see, in the second column of Table I, England had a much greater superiority over Germany than indicated in the third column for battleships of Dreadnought type. Incidentally, Table I makes it clear why the United States is just yielding the place of the second naval power to Germany. Of completed battleships the United States even yet has more tons than Germany, but the latter country is building so many more tons that the United States will never regain second place unless there is a marked change of policy on the part of one country or of both.

Of course, the customary gauging of naval power by tonnage is not an exact method of determining fighting power, but there is no accepted method by which we can determine this except, perhaps, actual war. Even tonnage statistics are not strictly comparable. We know that we use two kinds of tons in this country, the short ton and the long ton. For measuring displacement of battleships there are virtually as many different kinds of tons in use as there are nations.

A freight steamer may be able to carry in cargo double the weight of her hull and machinery. Her displacement then may vary 200 per cent. from her empty displacement. A battleship has a much larger proportion of fixed weight, but carries a large

removable or variable load in her coal, ammunition, stores, and water. Such weights may amount to eighteen or twenty per cent. of the empty weight of a large battleship. It is the practice to include arbitrary amounts of consumable weights when fixing the legend displacement of a battleship, and, as the practice in this respect of the various nations varies, the designed or official displacement of a given battleship would be different in each country.

In most countries the designed displacement of a battleship corresponds to a condition in which she carries a rather small proportion of her capacity of consumable weights. That was also the practice in the United States until about three years ago, when a much larger proportion of consumable weights was included in the designed displacement. A 20,000-ton vessel under our previous practice, which was close to the average foreign practice, would be, say, a 21,500-ton vessel under our present practice.

There is another little peculiarity about warship tonnage as customarily stated. The displacement of a battleship is the designed displacement and never changes. We have never had much experience of vessels materially exceeding their designed displacement—I believe no vessel of war built on the designs of the Navy Department since 1903 has exceeded her designed displacement by a single ton—but I know of cases of vessels such as the Dreadnought herself which notoriously exceeded their designed displacement when completed, yet are carried on all lists at the displacement of their original design.

Of course, the question of the proportion of consumable weights to be included in the official displacement of a battleship is largely one of expediency. Whatever the practice in this respect, the designer, in fixing position of armor and such matters, must, of course, consider all conditions of loading.

If the official displacement of a battleship is fixed rather light, she will make a slightly better speed on trial—the difference is very slight indeed for large battleships—and if existing tonnage is minimized, the chance of legislative authorization of more is improved. If, on the other hand, the official displacement is fixed rather heavy, since consumable weights which make her heavy are not included in cost of construction, the battleship will be cheaper per ton of displacement.

OFFENSIVE POWER.

A battleship, as you know, is a very complicated matter, a complete design being evolved by art as well as by science from many conflicting considerations. Perhaps the most salient characteristics bearing directly upon war efficiency are offensive power, speed and endurance, and defensive power.

There are many other essential characteristics, such as habitability, strength of structure, stability in intact and damaged condition, seaworthiness, etc., but for present purposes we must largely take these for granted.

In making Table I we adopt as the dividing line between the Dreadnought type and pre-Dreadnought types the characteristic of carrying a main battery of all big guns 11 inches or more in calibre. The Dreadnought was by no means a wholly novel type. The name has been borne in succession by a number of British men-of-war, and, curiously enough, when we compare the Dreadnought of 1905 with her immediate predecessor completed in 1875 (just thirty years before the Dreadnought of the present day was laid down) we find that the Dreadnought of 1875, like her successor, was, when completed, the largest, fastest, most powerful, and most heavily armored British battleship. Her main battery was uniform in calibre, consisting of four muzzle-loading rifles of 12.5 inches calibre, mounted in turrets. She carried also six rapid-fire guns—called then quick-firing—of 2½ inches calibre. The Dreadnought of 1905 carried a main battery uniform in calibre consisting of ten breech-loading rifles of 12 inches calibre, mounted in turrets. She carried also twenty-seven rapid-firing guns of 3-inch calibre. Each of these Dreadnoughts had an armor belt extending from end to end; its thickness amidships was 11 inches in each case.

Compare then how we may, the twin-screw, reciprocating-engined, 14-knot, 10,800-ton Dreadnought of 1875 shows remarkable similarity of type to the four-screw, turbined, 18,000-ton, 21½-knot Dreadnought of thirty years later. One naturally asks how it happens that in 1905, when making a marked advance in battleships, there was recurrence to the type of 1875, particularly as regards battery. The reasons, I think, are two-fold. In the first place, in thirty years the process of evolution had nearly completed its cycle and the battery was approaching again

the type of a generation before. There are on a battleship but two really satisfactory locations for turrets carrying heavy guns. One is forward of the machinery spaces in the centre line of the ship, and the other is aft of the machinery spaces, also in the centre line of the ship. So we find successors to the Dreadnought of 1875 in the English Navy mounting usually four heavy guns in these locations. But there was a steady evolution from the half dozen 2½-inch quick-firing guns of the old Dreadnought. The secondary battery grew into an auxiliary battery plus a secondary battery, so that in fifteen years, or about 1890, we find British battleships carrying four heavy or main battery guns as before, but instead of a few puny quick-firing guns they carried ten or a dozen 6-inch guns, protected behind armor, in addition to smaller guns still.

These 6-inch guns, combined with four heavy 12-inch guns, remained the standard, one may say, for some ten years or so. In the King Edward class, designed about 1901, we find a change. Their immediate predecessors carried four 12-inch guns, twelve 6-inch guns behind armor and sixteen 3-inch guns unprotected. The King Edwards carried four 12-inch, four 9.2-inch in turrets, ten 6-inch behind armor and twelve 3-inch unprotected. This was the first appearance of the 9.2-inch gun upon the British battleship. The next British class—the Lord Nelsons—laid down in 1904, abandoned the 6-inch gun. The Lord Nelson carried four 12-inch, ten 9.2-inch in turrets, and fifteen 3-inch unprotected. Here, then, we have two sizes of heavy turret guns, and it is quite reasonable to suppose that in time the 9.2-inch guns would have grown larger until by natural evolution the all-big-gun one-calibre ship would have appeared.

But there was a second factor which accelerated the slow process of evolution. For thirty years, to my knowledge, it has been a truism of the ordnance officer that the gun is a weapon of precision. Indeed, the precision of heavy guns is astonishing. Twelve-inch shells fired from a modern high-powered gun and leaving the gun in exactly the same direction with exactly the same velocity may be expected in still air to strike a target 10,000 yards, or say 5⅔ miles, away within a very few feet of each other. But, strangely enough, up to some ten years or so ago no navy appears to have realized the possibilities of the gun, or, at any rate, to have developed accuracy of shooting to an extent

approaching anywhere near the inherent possibilities of precision of the gun. I think it may be justly claimed that the shooting of the United States Navy has always been as good as that of any other nation. In the Spanish-American war the shooting of the United States vessels was obviously far superior to that of the Spaniards, but, even so, the percentage of shots that hit was painfully small, and it is only the hits that count. But about the year 1900 there began a movement for improvement. It originated in the British Navy, but their first improvements were very soon adopted in the United States Navy, and both made rapid and remarkable progress. Telescopic sights were adopted and perfected. Formerly the gun sighter had to look simultaneously at his rear sight, his front sight, and the target. With the telescopic sight he has simply to look at the target. Cross wires in the telescope which to the gun sighter seem to be in the plane of the target show the point of the target where the shot will strike if the sighting is correct. Methods were devised for increasing the rapidity of loading and for facilitating training and elevating guns so that, regardless of the motion of the ship, the gun could be kept always pointed on the target and could be fired as fast as loaded. Guns, of course, were fitted with sight bars adjustable for the various ranges and also to allow for wind, etc., but it was soon found that there were variables present which no sight bar could take account of. For instance, after a gun had been warmed up by firing a number of shots it would not shoot quite the same as when cold. Two charges from different lots of powder would not shoot alike. Charges from the same lot of powder, if of different temperatures when loaded, would not shoot alike. Careful and systematic endeavors were made to eliminate or reduce to rule the above and other variables liable to produce erratic shooting, and it was found in the end that the most hits were made if the sight bar was corrected as necessary from observations of previous shots. Hence the development of observation stations as high up as possible, so that the "spotters," as they are called, can follow the fall of shell at extreme ranges. Elaborate systems of communication were also developed, so that the fire control officers at the spotting stations could readily communicate necessary instructions to all guns.

Now it was found very early in the evolution of methods of fire control that the problem was very much complicated when it

was attempted to handle simultaneously two different calibres of guns. Also, the largest guns were much more accurate at the longest ranges. Hence there arose a demand from gunnery officers for uniformity of calibre of heavy guns just about the time when, by a process of natural evolution, we were approaching this type. Accordingly we find the British Dreadnought and the American Michigan, which was designed very soon afterwards, carrying 12-inch guns and 3-inch guns only, the intermediate calibres, which were 7 inches and 8 inches in America and 6 inches and 9.2 inches in Great Britain, having disappeared.

It is interesting to note that at once the process of evolution again began. The small guns were called the torpedo defense battery and were supposed to be of use only against torpedo vessels. But in England the 3-inch guns of the Dreadnought were replaced by 4-inch guns on her successors, and it is currently reported that the most recently laid down English battleship is to carry a torpedo defense battery of 6-inch guns. In the United States the 3-inch guns of the Michigan were followed by the 5-inch guns of the Delaware, and on later vessels there is carried an improved type of 5-inch gun about as powerful as the 6-inch gun of ten years ago. Other nations which took up the Dreadnought type later never abandoned the 6-inch gun. Hence we may say that, broadly speaking, on the average the type of battery of to-day is again that of ten or fifteen years ago, consisting of a number of heavy guns in turrets and a number of 6-inch guns in broadside. The differences are that on the much larger ships two or three times as many heavy guns are carried and the 6-inch guns are not so well protected, being regarded by many designers as useful against torpedo craft only. With the increase in size of torpedo craft and in range of the torpedo we may anticipate a demand for torpedo defense guns which will put torpedo vessels out of action at longer ranges, and probably for larger calibres which are more accurate at the longer ranges. The art of fire control has not stood still, and the problem of the control of a mixed battery is not so difficult as it was some years ago. While the only thing that may be safely prophesied is that present types will be developed into others, it seems reasonably certain that the evolution of the torpedo defense battery of to-day will be along one of two lines.

The torpedo defense battery will be made larger in calibre,

given more protection, and relied upon for use in action against battleships, so that we will return to a mixed battery type, or the main battery will be relied upon for torpedo defense work and the torpedo defense battery will disappear.

In concluding what I shall say about armament I would invite your attention to Fig. 1, indicating by skeleton deck plans the main battery distribution of the most recent battleships of the principal naval powers. Broadly speaking, the heavy turret guns monopolize the commanding positions and the small guns have to be given what is left. Most nations, the United States among them, locate the torpedo defense guns below the heavy guns. They are thus better protected and easily supplied with ammunition, but are objectionably close to the water. Great Britain has hitherto located torpedo defense guns at the level of and above the heavy guns. It is much more difficult to carry 6-inch guns thus than 4-inch guns, and if it is a fact that England has come to 6-inch torpedo defense guns it is very probable that the change in calibre will be associated with a change in disposition.

As to the heavy guns, the disposition, as shown in Fig. 1, is most varied. I have already mentioned that the only satisfactory locations for turrets carrying heavy guns are forward and aft in the centre line. Broadside fire is paramount under present conditions, as it is generally admitted that ships will fight broadside to broadside rather than end on.

A centre line mounting is the only one that permits a gun to be used with equal effect on each broadside. A gun mounted in the centre line forward can also be used forward and one so mounted aft can be used aft. A gun mounted in the centre line near the middle of the ship can be used, as a rule, for broadside fire only, and generally for rather a limited range only. Having in view the necessities of the machinery, it is difficult to provide satisfactory ammunition stowage for guns mounted near the middle of length of a ship.

As exemplified by the diagram of the Michigan in Fig. 1, it has been the practice in the United States Dreadnoughts to carry two heavy turrets at each end, thus having four turrets in the most satisfactory location. Additional turrets are located in the centre line.

With two turrets at the end one must fire over the other. As this American arrangement has had the flattery of imitation by nearly all foreign nations, the history of its adoption may be

of interest. It was first seriously proposed and advocated by the Bureau of Construction and Repair in 1895 in connection with the Kearsarge design. It was proposed then to locate an 8-inch turret behind and firing over a 13-inch lower turret. The gunnery experts of the day claimed that under such conditions the lower turret would be uninhabitable. The idea lingered, however, and about 1904–5 a thorough test was made upon the recommendation of Chief Constructor Capps. After preliminary experiments at the Proving Ground a crucial test was made on the monitor Florida. A 12-inch gun was removed from her turret and mounted so as to fire over it. Simple changes were made in the turret roof and the 12-inch gun was fired over it a number of times. The tests were progressive, the turret being occupied, I believe, first by four-footed animals, then by midshipmen, and so on up to rear-admirals. With the turret top of proper thickness and tightly closed it was found perfectly feasible to occupy and work the lower turret when the upper turret is firing—a thing which will seldom be done, by the way—never in broadside firing.

Fig. 1 shows clearly that the latest battleships of nearly all nations have adopted this disposition.

It is seen from Fig. 1 that heavy turrets that are not placed near the ends in the centre line are disposed according to three methods.

1. On the broadside firing on one side only.

2. On the broadside firing through a large arc on one side and a restricted arc on the other.

3. In the centre line firing equally on each broadside.

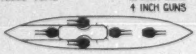
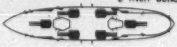
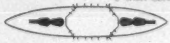
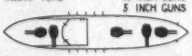
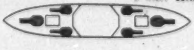
The first arrangement has the serious drawback that a turret so mounted can be used on one broadside only. It is seen that the United States never adopted it for the heaviest guns, and England and Germany have abandoned it.

The second arrangement has the disadvantage that the arc of fire across the deck is usually very restricted—and more restricted, as a rule, upon the actual ship than upon the design. It has also the disadvantages, common to all large broadside turrets, that the opening in the deck for the barbette below the turret is a source of weakness of structure difficult to make good, and that the magazines below are much more liable to be exploded by torpedoes or mines than in the central location.

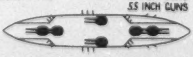
With this broadside arrangement we find generally one turret

FIG. 1

BATTERIES OF BATTLESHIPS AND SUBSEQUEN

YEAR OF LAYING KEEL	GREAT BRITAIN	GERMANY	UNITED STATES	JAPAN
1905	DREADNOUGHT 1 VESSEL 17,900 TONS 12 INCH GUNS 12 POUNDERS 	HANNOVER CLASS 4 VESSELS 13,200 TONS 11 INCH GUNS 6.7 INCH GUNS 	VERMONT CLASS 6 VESSELS 16,000 TONS 12 AND 3 INCH GUNS 7 INCH GUNS 	SATSUMA CLASS 2 VESSELS 19,250 TONS 12 AND 10 INCH GUNS 6 INCH GUNS
1906	BELLEROPHON CLASS 3 VESSELS 18600 TONS 12 INCH GUNS 4 INCH GUNS 	NASSAU CLASS 4 VESSELS 18,500 TONS 11 INCH GUNS 6 INCH GUNS 	SOUTH CAROLINA CLASS 2 VESSELS 16,000 TONS 12 INCH GUNS 3 INCH GUNS 	
1907	ST. VINCENT CLASS 3 VESSELS 19,250 TONS 12 INCH GUNS 4 INCH GUNS 		DELAWARE CLASS 2 VESSELS 20,000 TONS 12 INCH GUNS 5 INCH GUNS 	
1908		THÜRINGEN CLASS 4 VESSELS 21,000 TONS 12.2 INCH GUNS 6 INCH GUNS 		
1909	NEPTUNE CLASS 3 VESSELS 20,200 TONS 12 INCH GUNS 4 INCH GUNS 	KAISER CLASS 3 VESSELS 23,000 TONS 12.2 INCH GUNS 6 INCH GUNS 	UTAH CLASS 2 VESSELS 21,325 TONS 12 INCH GUNS 5 INCH GUNS 	KAWACHI CLASS 2 VESSELS 20,750 TONS 12 INCH GUNS 6 INCH GUNS 
1910	ORION CLASS 5 VESSELS 23,500 TONS 13.5 INCH GUNS 4 INCH GUNS 		ARKANSAS CLASS 2 VESSELS 26,400 TONS 12 INCH GUNS 5 INCH GUNS 	
1911			TEXAS CLASS 2 VESSELS 27,000 TONS 14 INCH GUNS 5 INCH GUNS 	

. 1
IIPS LAID DOWN IN 1905
UENT YEARS

FRANCE	ITALY	AUSTRIA	RUSSIA	YEAR OF LAYING KEEL
	SAN GIORGIO CLASS 4 VESSELS 9,330 TONS 10 AND 12 INCH GUNS 12 POUNDERS 			1905
				1906
DANTON CLASS 6 VESSELS 18,400 TONS 12 AND 9.4 INCH GUNS 12 POUNDERS 		RADETSKY CLASS 3 VESSELS 14,500 TONS 12 AND 9.4 INCH GUNS 4.1 INCH GUNS 		1907
				1908
	DANTE ALIGHERI 1 VESSEL 19,000 TONS 12 INCH GUNS 4.7 INCH GUNS 		GANGOOT CLASS 4 VESSELS 23,300 TONS 12 INCH GUNS 4.7 INCH GUNS 	1909
COURBET CLASS 6 VESSELS 23,467 TONS 12 INCH GUNS 5.5 INCH GUNS 	CONTE DI CAVOUR CLASS 3 VESSELS 21,500 TONS 12 INCH GUNS 4.7 INCH GUNS 	TEGETTHOF CLASS 4 VESSELS 20,000 TONS 12 INCH GUNS 4 INCH GUNS 		1910
				1911

on each side near the middle of the ship. On paper such turrets are generally indicated as firing from right ahead to right astern. As a matter of fact, it is not practicable in most cases to fire right ahead or right astern without serious damage to the ship from the blast.

The third arrangement has the advantage from nearly all points of view, except that when two turrets are used and it is necessary to raise one in order to permit train across the deck, it is slightly heavier than the broadside arrangements.

We see from Fig. 1 that at a comparatively short time after the adoption of the all-big-gun type of ship many nations increased the size of these big guns. England went from 12 inches to 13½ inches in the Orion, laid down in 1909. The United States went from 12 inches to 14 inches in the Texas, laid down in 1911. Germany went from 11 inches to 12.2 inches in the Thüringen, laid down in 1908, and there are rumors in the papers that she is about to increase again her big-gun calibre, and that other nations who have not surpassed 12 inches are about to do so.

The introduction of a new calibre of heavy guns into a navy is a large undertaking and results in permanent complications as regards manufacture and supply of ammunition. I regard it as doubtful if the calibre of 14 inches now used by the United States will be exceeded in the near future by any nation. Looking backward, it may be recalled that eight out of our first nine battleships carried 13-inch guns of rather low power and that in 1899 we made a reduction of bore, adopting the 12-inch calibre—of high-power type.

Before leaving the question of offensive power I will touch very briefly upon the torpedo battery of battleships. The torpedo is a weapon which cannot be ignored, but, being at best complicated, easily deranged, and erratic, it has never shown in practice capabilities claimed for it by its advocates. It is primarily the weapon of the torpedo craft, but battleships carry them too—from two to six submerged torpedo tubes being carried by the latest battleships. Torpedoes have been improved during the last few years, and with their increase in size and range they would now be a very formidable addition to the battleship's offensive power were it not for the fact that the increase in fighting range due to improvement in gunnery has been relatively even greater than the increased range of the torpedo.

The torpedo battery of battleships will continue to be a strong incentive to induce battleships to do their fighting at ranges beyond that of the torpedo, and naturally to prevent any recrudescence of ramming tactics in battleship actions. Ramming tactics became obsolete as soon as the torpedo became a dangerous weapon, more than a quarter of a century ago.

SPEED AND ENDURANCE.

The question of the proper speed for a battleship is one concerning which designers differ more, perhaps, in theory than in practice. Italy is the only nation which has consistently for many years attached great value to high-speed battleships. With the exception of Italy, we may almost say that the standard battleship speed at the time of the Dreadnought design was about nineteen knots; the great majority of battleships were designed for that speed within half a knot above or below. The designed speed of the Dreadnought class was twenty-one knots, and most of the nations in their latest ships aim at battleship speeds above twenty knots.

The maximum speed of a battleship is, in the public eye and in tables of data, a constant quantity. We find it always stated as the maximum speed attained or alleged to be attained on trial. As a matter of fact, there is no characteristic of the battleship so variable and indefinite as the actual maximum speed which it can show at any given time. The wind and the sea will materially affect speed, their influence, of course, being transitory. Foulness of bottom due to the length of time out of dock may readily reduce the maximum speed two knots or so below what might be otherwise attained. The condition of the machinery, the efficiency of personnel, the chapter of accidents all affect speed and render it variable and uncertain.

The possible speed of a fleet is, of course, the maximum speed of the slowest vessel in it, and hence the speed of a fleet is apt to be very much less than the maximum on trial of any individual member of the fleet, since a large fleet is almost certain to have one or more lame ducks.

To the popular mind, particularly in America, speed seems to appeal in a peculiar fashion. Superiority of speed seems to imply somehow superior fighting qualities, just as quickness in a pugilist is associated with fighting ability.

As a matter of fact, speed appears to be of more value strategically—that is to say, during the moves previous to actual contact—than tactically—that is to say, during actual battle. A number of years ago investigations at the United States Naval War College led our experts to the conclusion that, as regards battleships, superior speed was not of great advantage for the probable conditions of actual battle unless superiority was very marked, say three or four knots.

In those days, moreover, the probable fighting ranges in battle were taken to be 2,000 yards or so. The fighting range has now grown to 10,000 yards or more. Bearing this in mind, it is obvious that the relative superiority given by three or four knots advantage of speed when fighting at 2,000 yards would require an advantage of probably eight to twelve knots when fighting at 10,000 yards. Without pursuing this line further, I think it may be safely stated that for battleships the main advantage of speed is the ability it confers to refuse action, which is a polite expression for running away. The next advantage of speed is the ability it confers to force action, or to catch an enemy who is running away.

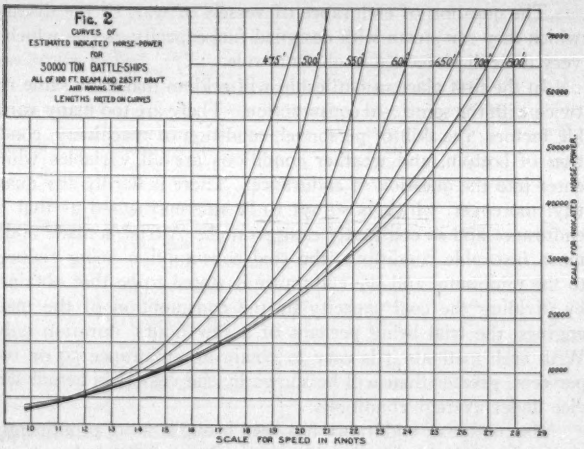
Once battle is joined battleship speed is of comparatively minor value.

The penalties of speed, or the sacrifices which must be made to attain speed, are very large indeed. One might think, at first sight, that it would simply be a question of giving up so much weight of armor or armament and putting it into machinery. This, however, is very far from being the case. The indirect sacrifice, particularly as regards protection, necessary to obtain speed is much greater than the direct sacrifice. This is mainly because high speed is necessarily associated with great length. This fact is illustrated by Fig. 2, which shows the estimated curves of horsepower for a series of 30,000-ton battleships, all of the same beam—100 feet—with the same draft—28½ feet. The influence of length upon speed, sometimes enormous and always important, is obvious from the diagram.

If we assume that in each case we could put a maximum of 70,000 horsepower into the vessel, which is somewhere near the truth, we see that if she were made 500 feet long the speed would be twenty-one knots, whereas if she were made 800 feet long the speed would be twenty-eight knots.

It is doubtful if sufficient length and space could be given to machinery in a 500-foot vessel to enable 70,000 horsepower to be developed; probably it would not be possible to drive such a vessel over twenty knots, owing to limitation of space for machinery.

However, assuming, for the present, that we could get 70,000 horsepower into each vessel, the weight of machinery would be approximately the same, regardless of the length of the vessel; but to build a 30,000-ton vessel 800 feet long would take a very much greater weight of hull than to build a 30,000-ton vessel 500



feet long. This additional weight of hull would have to come from the armor or armament, the 30,000 tons of displacement being fixed. Moreover, the thickness of armor protection for a given weight which could be placed on an 800-foot vessel would be very much less than for the same weight applied to a 500-foot vessel.

It is evident, then, that the penalty paid for speed besides the direct weight necessary to provide for machinery is the additional weight of hull necessary to provide a vessel of the length and form to enable it to be driven at the higher speed, and, superposed

upon this, the diminution of the armor thickness, or the restriction of the proportion of the area of the ship protected by armor resulting from the greater length to be protected. The solution of the problem of speed is then obviously a compromise between conflicting considerations, as is the case of so many other problems of warship design. For the latest United States battleships the designed speeds have varied from twenty and a half knots to twenty-one knots, trial speeds usually being a little better by half a knot or so.

It will be seen from Table II that these speeds are close to the average of those chosen by foreign nations.

The question of endurance of vessels of war, or the distance which they can steam with designed fuel capacity, is one which is very difficult to reduce to absolute rule.

In the first place, a battleship will seldom make the same run twice with the same coal consumption. There are too many variable factors; the skill of personnel, condition of machinery, condition of bottom, and weather conditions are all variables which enter into the question of endurance. There is hardly any quantity, moreover, which is so apt to be misrepresented as that of endurance and so constantly exaggerated. A trial is made under most favorable conditions, the coal consumption being reduced to the minimum, and the endurance is stated to be that obtained by dividing the coal capacity by the consumption of the main engines, the trial being perhaps of a few hours' duration only. With such methods it is easy to obtain an endurance 50 or 100 per cent. greater than will be shown by the vessels in actual service under average conditions.

The matter of endurance has been brought more prominently to the front during the last few years by reason of the almost universal adoption of turbines for the propelling machinery of battleships. These have the unfortunate feature that if designed to give the best speed or the best results at or near the top speed, while giving better results for these conditions than reciprocating engines, they are very much less efficient than the reciprocating engines at ordinary cruising speeds. Now if the greatest endurance is aimed at, it is necessary to steam at quite a low speed, below ten knots, in fact, but ordinarily endurances are figured on the basis of a ten-knot speed.

The net work done in driving a ship over a distance is pro-

portional to the resistance and to the distance over which the resistance is overcome. For a constant distance the net work is proportional to the resistance, and if the resistance decreases indefinitely with speed the net work will also so decrease. But with any type of machinery the ratio between the net and gross

TABLE II.

Designed Speeds and Armor Thickness of Recent Battleships of Various Nations. (From Jane's Warships.)

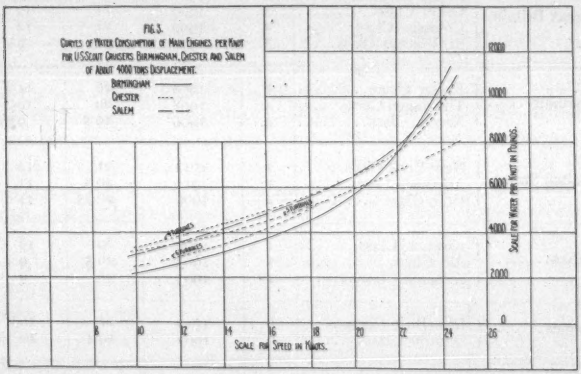
Nations.	Vessels.	No. in class.	Year of laying down first of class.	Designed speed, knots.	Thickness of armor belt, maximum.
					Inches.
Great Britain.	Monarch Class	5	1910	21	12
	Orion Class	3	1909	21	12
	Colossus Class	2	1909	21	12
	St. Vincent Class	3	1907	21	9¾
Germany	Kaiser Class	8	1909	20	11¾
	Thüringen Class	4	1908	20	10¾
	Nassau Class	4	1906	19.5	9¾
United States.	New York Class	2	1911	21	12
	Arkansas Class	2	1910	20.5	11
	Utah Class	2	1909	20.75	11
Japan	Kawachi Class	2	1909	20	12
	Aki Class	1	1905	20.5	9
	Satsuma Class	1	1905	20	9
France	Jean Burt Class	6	1910	21	10¾
	Danton Class	6	1907	19.4	10
Italy	Conte di Cavour Class	3	1910	22.5	..
	Dante Alighieri Class	1	1909	23	..
Austria	Tegetthof Class	4	1910	21	11
	Radetzky Class	3	1907	20	9
Russia	Gangoot Class	4	1909	23	11
	Imperator Class	2	1903	18	8½

work will decrease at low speeds as the speed decreases, so there will be some low speed at which the gross work done in steaming a given distance will be a minimum. In practice the speed for minimum gross work or maximum endurance is inconveniently

small, but in most cases the endurance at the convenient speed of ten knots is almost as great as the maximum possible endurance.

The reduced economy of the turbines is associated not only with the economy of the turbine proper, but with the reduced efficiency of the type of propeller, which must be adopted to give the best all-round results for the turbine, hence the only fair basis of comparison is one involving all of the factors.

I have attempted to make such a comparison between the scouts Birmingham, Chester, and Salem, tried two or three years ago. The Birmingham was fitted with reciprocating engines, and the Chester and Salem with turbine engines of different types. The curves of Fig. 3 show the pounds of water used by the main



turbines per knot for various speeds. The Chester, being fitted with various combinations, required three curves.

The basis of pounds of water used per knot was adopted in order to eliminate as nearly as possible the effect of type of boiler, efficiency of firing, etc.

I will invite attention to two facts brought out by Fig. 3. In the first place, the curves are still falling off at the speed of ten knots, so that if these vessels were to steam the maximum possible distance, time being not important, it would be policy, as already indicated, to adopt a speed even below ten knots.

In the second place, the Birmingham, with reciprocating engines, shows markedly better economy at the low speeds and worse at the high speeds.

Incidentally it may be remarked that the maximum trial speed of the Birmingham was materially below that of the two turbine vessels.

Although turbines have been adopted by practically all nations, including ourselves, for battleships, the superior economy of the reciprocating engines at cruising speeds caused us to return to them for the Texas and New York, now under construction, and contracted for a little over a year ago. Of our two battleships just contracted for, the Nevada and Oklahoma, one will have reciprocating engines and the other turbines arranged so as to promise better economy than hitherto.

Many devices have been proposed for obtaining the advantages of the turbines at high speeds and good economy at low speeds.

To gain the maximum steam economy for the turbine it should revolve much faster at high speeds than has been the practice, while the propeller of maximum economy should revolve much more slowly. When directly connected each hampers the other.

Among the methods to increase the economy of turbine-driven ships, I may note the following:

1. Gearing the turbine shaft to the propeller shaft. Then the turbine can run as fast as desired and the propeller shaft as slowly as desired within the limitations of the gearing. This method has been used abroad on merchant vessels with claims of success, and is being tried on a United States collier.

2. Indirect electrical drive—turbine of maximum economy driving electric generators, which in turn drive electric motors on the shafts.

This method is being tried on a United States collier under construction. It is heavier and more complicated than the simple gearing, but is more flexible than the gearing method and can be used for powers larger than would be undertaken with gearing at present.

3. Small reciprocating engines, to be clutched in at cruising speed and thrown out at high speeds, which exhaust to the turbines. This method is being tried on a United States torpedo

boat destroyer under construction, and shore tests of the apparatus indicate marked gain in economy.

As might be expected, each method tried has difficulties and objections peculiar to it, but steady progress is being made, and probably it will not be long before a satisfactory solution will be evolved. It appears to me that at present for vessels carrying the whole or a large proportion of their fuel supply in the form of oil, as do our most recent battleships, the ideal solution would be to fit Diesel engines, or the equivalent, driving generators, which in turn drive motors upon the shafts; this installation, however, to be of low power, adapted to drive the ship about ten knots only. For higher speeds turbines and boilers would be relied upon.

Such an arrangement would be slightly heavy as regards weight, but would have the advantage that the endurance would be doubled at cruising speed and an entirely independent means of propulsion would be provided, giving reasonable insurance against breakdowns. It would also be a step towards the generally anticipated use of the oil engine only for propulsion.

Such an installation would involve some difficult engineering problems, but I know of no reason why they could not be satisfactorily solved.

PROTECTION.

Let us now consider briefly the question of the protection of battleships.

In this connection we need to consider attack by gun fire, by torpedoes, by mines, and by explosives dropped from aëroplanes. The principal things to be protected are the buoyancy of the battleship, her stability, her vitals below water, such as engines, boilers, steam pipes, magazines, and steering gear; her armament; and the personnel directing the operation of the vessel.

As regards gun fire, we rely for protection almost entirely upon armor, whether vertical armor on the sides or horizontal or sloping armor in the shape of a protective deck. It is evident that if the ship were composed of a very large number of small watertight compartments it would take a number of shots to destroy her buoyancy and stability, since each shot would reach but a limited number of the compartments. This principle of subdivision is relied upon to some small extent for protection against

gun fire, but, as already stated, our main protection must be armor.

An ideal system of protection against gun fire would be one where the sides are covered with impenetrable armor from a point below the water line, as low as will ever be attacked by shell, to a point sufficiently high above the water line to insure that the ship would always retain her buoyancy and stability.

If, at this upper level, there were worked a level impenetrable deck we would have protection of buoyancy, stability, and vitals.

To complete this conception we should have, rising from this upper level, impenetrable armor superstructures carrying impenetrable turrets, impenetrable conning towers, etc. Needless to say, this ideal is not attained in practice. The demand for offensive power and speed in battleships is so great that defensive power in many cases falls far short of the ideal and in no case actually reaches it.

Full information as to actual armor protection of the battleships of the various nations is very difficult to obtain. Half a dozen battleships of the same size, carrying the same total weight or armor, would distribute it somewhat differently. However, as a rough gauge of armor protection we may use the maximum thickness of the main belt. This is given in Table II for a number of the most recent ships of various nations, the latest ship in each case coming first.

It will be observed that there is a tendency in nearly every nation to increase armor protection, judging by the maximum side armor thickness given. Another fact noticeable from the table is the comparatively close agreement of a number of nations in the maximum side-armor thickness of their most recent ships. This is 12 inches in Great Britain, Japan, and the United States, 11¾ inches in Germany, 11 inches in Austria and Russia, and 10¾ inches in France. There is no information as to the Italian ships, but, considering their speed, it is not likely that their armor is very heavy.

For many years there have been two opposing classes of thought as regards armor protection. On the one side we find the greatest importance given to the side armor with the idea of keeping the shell out of the ship as long as possible; on the other side we find great importance given to the horizontal armor, or sloping armor, the idea being that the shell would not do much

damage provided it does not reach the vitals. Hence, we find material variations in the relative weights devoted to protective decks and side armor.

As illustrating current ideas of armor protection I invite attention to Fig. 4, giving the approximate distribution of armor upon some of the best protected of the most recent battleships; namely, the Argentine Republic battleships Rivadavia and Moreno, building in American shipyards upon American designs. It is seen that we have first a 12-inch belt extending over the midship portion of the vessel and tapering slightly forward and aft until we pass the last heavy gun position, where it drops abruptly to a thickness of five or six inches. Above this belt is a uniform thickness of nine inches of armor extending to the upper deck and protecting the bases of turrets, smokestacks, engine hatches, etc. The barbettes and turrets rise above this level, their protection being about equivalent to that of the main belt. We also have conning towers projecting above this level.

The main protective deck, with a flat portion above the water line and sloping to the bottom of the side belt, is 2-inch nickel steel, and at a high level we have also 6-inch armor protecting the 12- to 6-inch guns. There are, in addition, a number of 4-inch guns mounted without protection on top of turrets and elsewhere. Below water we have a heavy bulkhead worked about 10 feet within the side, intended primarily for protection against torpedoes.

The question of protection against torpedoes is one which is by no means solved. The usual practice has been to make compartments as small and as numerous as possible where torpedo explosions were liable to occur, and the larger the size of ship the less the danger that a single torpedo would put her out of action.

In the war between Japan and Russia there were some very striking examples of the deadly effect of submarine mines carrying large charges of high explosives. During that war the torpedoes did not score many hits, and, when they did score a hit, did not accomplish the damage which had been anticipated by torpedo enthusiasts. But since then the speed, accuracy, and weight of explosives carried by torpedoes have all been increased, and there has been developed the torpedo gun, or a torpedo carrying in a "gun" a shell charged with high explosives,

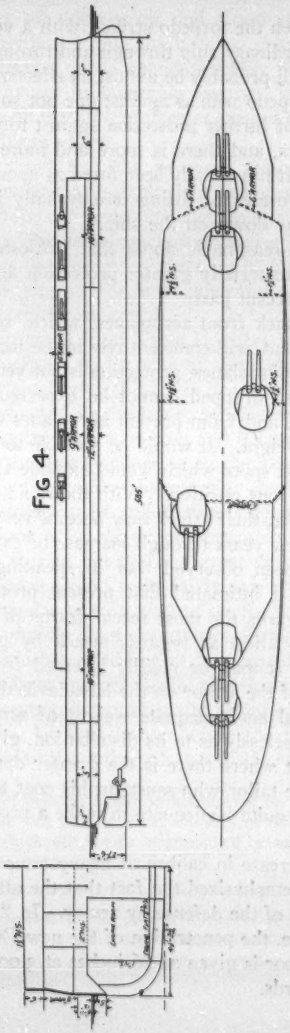


FIG 4

Distribution of arms upon Argentina battleships.

which is fired, when the torpedo strikes, with a velocity sufficient to penetrate the ordinary ship through and through.

This device will probably be almost as effective against a ship protected with torpedo nets as against one not so protected.

The question of further protection against torpedoes has been talked of for years, and there is more and more tendency to fit such protection. It has usually been fitted as upon the Rivadavia, but there are advocates of fitting it externally in the shape of external armor far down on the ship.

There is little reasonable doubt that battleships of the near future will carry materially greater protection against torpedoes than those of the recent past.

As regards attack from aëroplanes, which, so far as can be anticipated at present, will come entirely in the form of explosives dropped from the aëroplanes, protection is not yet a difficult matter. Any bomb so dropped cannot be expected to have much penetrative power, and from present aëroplanes must have comparatively small weight. It would be possible to fit nets or light shelters above vital spots which would explode the bomb before it reached a dangerous position. With the rapid development of aëroplanes, however, their attack may become very serious within a comparatively few years through increase of carrying capacity.

It will have been observed that in speaking of protection against torpedoes I intimated that present protection was not satisfactory as regards the most recent forms of attacks by this weapon. The situation as regards attack by gun fire is also not satisfactory. It may be readily inferred from the varying thicknesses, etc., of the armor on the Rivadavia that the designer had at his disposal an inadequate weight of armor and has to ponder almost ceaselessly as to its distribution, giving, of course, the greater weight where there is the greater danger. He is in the position of the tailor who must cut his coat to suit his cloth, but finds his cloth quite inadequate to make a proper coat of any fashion.

The recent increase in calibre of heavy guns in this country and England has emphasized the fact that the attack by gun fire is markedly ahead of the defense by armor. In "Fighting Ships for 1911," by Jane, the penetration of the new British 13½-inch gun in Krupp armor is given as 26 inches at 3,000 yards and 22 inches at 5,000 yards.

While ranges of 3,000 yards and 5,000 yards have become very short for fighting within the last few years, the penetration of this gun at 10,000 yards would probably be 15 or 16 inches of armor, and, except in favorable weather, it would hardly be possible to carry on the fight at greater ranges than 10,000 yards, owing to difficulty of vision.

Bearing in mind that the heaviest armor carried by any British ship mounting 13½-inch guns is but 12 inches, we may say that these ships can penetrate their own sides as far as it is possible to see. The same conclusions will apply to the 14-inch gun mounted on the American ships, and, indeed, we may say almost the same thing of the more powerful of the 12-inch guns whose use is practically universal.

As may be inferred from Table II, there is a tendency to increase armor thickness as the size of ships increases, and in the most recent United States ships this has been carried materially further than indicated in the table; but increases hitherto made can hardly be regarded as adequate, and it must be admitted that at the moment the gun is superior to the armor. Whether the armor will again forge ahead by superior combination of old elements, the development of still further improved armor, or the devotion to armor of a larger proportion of the displacement, it is impossible to say, but there is great need for improvement in protection, and it would seem fairly safe to prophesy that for some years to come we may expect to see the protection developed relatively more rapidly than the attack. I think that is certainly the proper and much-needed line of development. An alternative is to give up the fight and practically abandon armor.

In this connection I would invite attention to some extracts from a paper by Admiral Bacon before the British Institute of Naval Architects in the spring of 1910. He says:

> The problem of building a ship which can not be sunk by the explosion of a torpedo is one that has exercised the skill of naval architects, and the design of a ship which will not be incapacitated by such attack has hitherto baffled all solution.
>
> * * * * * * * * * * * * * *
>
> As regards retention of the present thickness of armor protection, this is a matter which may before long undergo considerable modification, and the armor problem of the future appears to resolve itself into the answer to the following question:

Supposing the guns of the enemy can with certainty pierce armor protection at reasonable fighting range, what is the most economical thickness of armor to adopt? Very many considerations are involved in the answer to the question, such as the position and thickness of horizontal armor, but, considering the enormous sacrifice in weight now made to carry thick armor protection, it is a matter that before long may undergo bold and radical revision.

Developments since the paper of Admiral Bacon appear to indicate that the bold and radical revision in armor protection has not come as yet, though now overdue. If the protection does not soon relatively increase, the only thing to do will be to abandon protection, just as the knights in the Middle Ages threw away their armor after gunpowder weapons were developed, and to evolve entirely novel types of ships. Personally, however, I think that the armor maker and the naval designer will not give up the fight and that protection will gain on attack.

In this connection, while slightly apart from my topic, I might say a word or two about the fast armored cruisers, or "battle cruisers," now being built abroad. These vessels illustrate completely what I have said about the indirect effect of speed upon protection. They are as large as, or larger than, battleships, and their length is materially greater than that of the battleships, while their armor protection is very much less. They carry heavy guns, as heavy as battleships, although not so numerous, and presumably would have to fight battleships at times. Their protection is so very slight, however, that against modern heavy guns they are practically on a par with the old protected cruisers, and the value of an enormous ship which will be put out of action immediately upon sighting the enemy appears at most problematic. They undoubtedly have their use for other purposes than the line of battle, such as scouting, but the value of any ship for scouting is likely to be largely reduced in the very near future by the development of aëroplanes.

The very name "battle cruiser" is a contradiction in terms, and the type is far from fixed. The weight which they carry in the form of protection is largely wasted, since it affords wholly inadequate protection, and if this type is further developed along logical lines we may expect to see a great increase of size with protection brought up to that of the battleship or an abandonment of protection along the lines forecasted by Admiral Bacon.

THE STRUCTURAL COMPOSITION AND PHYSICAL PROPERTIES OF STEEL.

BY

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STRUCTURAL COMPOSITION OF SLOWLY COOLED STEEL.

BEARING in mind that hypo-eutectoid steel is composed of free ferrite and pearlite and that hyper-eutectoid steel consists of free cementite and pearlite, and knowing the proportion of carbon in pearlite (0.85 per cent.) and in cementite (6.67 per cent.), the structural composition of any steel may be readily calculated, provided we know the percentage of carbon it contains.

In case of hypo-eutectoid steel we have the following equations:

$$(1)\quad F + P = 100$$
$$(2)\quad \frac{E}{100} P = C$$

in which F represents the percentage of free ferrite in the steel, P the percentage of pearlite, E the percentage of carbon in pearlite, and C the percentage of carbon in the steel. The first equation expresses the fact that the steel is composed of ferrite and pearlite, and the second equation the fact that all the carbon in the steel is included in the pearlite. Assuming, for instance, that pearlite contains 0.85 per cent. carbon and the steel 0.50 per cent. carbon, the resolution of these two equations indicates that steel of that grade has the following structural composition:

F = per cent. free ferrite = 41.8.
P = per cent. pearlite = 58.2.

In case of hyper-eutectoid steel the following two equations may be written:

$$(1)\quad P + Cm = 100$$
$$(2)\quad \frac{E}{100} P + \frac{6.67}{100} Cm = C,$$

in which P represents the percentage of pearlite, Cm the percentage of free cementite, E the percentage of carbon in pear-

lite, C the percentage of carbon in the steel. The first equation expresses the fact that hyper-eutectoid steel is composed of pearlite and free cementite, and the second the fact that the carbon in the steel is distributed between the pearlite and the free cementite, forming E per cent. of the pearlite and 6.67 per cent. of the cementite. Assuming the value of E to be 0.85 and the steel to contain 1.25 per cent. carbon, these equations give for a steel of that grade:

$$P = \text{per cent. pearlite} = 93$$
$$Cm = \text{per cent. free cementite} = 7$$

Supposing that pearlite or eutectoid steel contains 0.85 per cent. carbon, since the whole of that carbon is present in the cementite plates of pearlite, and since cementite contains 6.67 per cent. carbon (as called for by its chemical formula, Fe_3C), the percentage of cementite in pearlite may be readily calculated as follows:

$$\frac{6.67}{100} \times \text{per cent. cementite} = 0.85$$

$$\text{hence, per cent. cementite} = 0.85 \times \frac{100}{6.67} = 12.74$$

$$\text{and per cent. ferrite} = 100 - 12.74 = 87.26,$$

or, roughly, 1 part by weight of cementite to 6.6 parts by weight of ferrite.

If it be considered, however, (1) that the exact carbon content of pearlite is not, and hardly can be, known, (2) that it varies somewhat both with composition and treatment, and (3) that in commercial steel it is probably not far from 0.85 per cent., we are fully warranted to assume, for the sake of the great simplicity it introduces in the calculations, that pearlite contains exactly 1 part by weight of cementite to 7 parts by weight of ferrite, which would be the case if the eutectoid point corresponded to 0.834 per cent. carbon, as indicated below:

1 part cementite + 7 parts ferrite yields 8 parts pearlite
or 12.50 per cent. cementite + 87.50 per cent.
ferrite = 100 per cent. pearlite;

and since cementite contains 6.67 per cent. carbon, 12.50 per cent. cementite will contain $6.67 \times .12.50 = .834$ per cent.

carbon. Assuming, then, that such is the carbon content of eutectoid steel, so that 1 part of cementite gives exactly 8 parts by weight of pearlite, and noting that the carbon in the steel produces exactly 15 times its own weight of cementite,[1] the calculation of the structural composition of any steel becomes extremely simple.

In case of hypo-eutectoid steel (steel containing less than 0.834 per cent. carbon) we have

per cent. total cementite = per cent. total carbon × 15
and per cent. pearlite = per cent. total cementite × 8;

or, more simply,

per. cent. pearlite = per cent. carbon × 120
i.e., $P = 120\,C$

and, of course, per cent. ferrite $= F = 100 - P$.

With hyper-eutectoid steel (steel containing more than 0.834 per cent. carbon) the figuring is as follows:

Since 8 parts of pearlite contain 7 parts of ferrite and since in hyper-eutectoid steel the totality of the ferrite (total ferrite) is included in the pearlite (there being no free ferrite), we have

per cent. pearlite = $P = \frac{8}{7}$ total ferrite
or, since total ferrite = 100 − total cementite,
$P = \frac{8}{7}$ (100 − total cementite).

But total cementite = carbon × 15, hence

$$P = \tfrac{8}{7}\,(100 - 15\,C)$$
$$\text{or } P = \frac{800 - 120\,C}{7}$$

and, of course, free cementite $= Cm = 100 - P$.

Summing up, in order to find the percentage of pearlite in hypo-eutectoid steel it will suffice to multiply its carbon content by 120 ($P = 120\,C$), the balance of the steel, consisting, of course, of free ferrite ($F = 100 - P$); to find the percentage

[1] This follows from the composition of Fe_3C indicated by the atomic weights of iron and carbon:

(3 × 56) Iron + 12 Carbon = 180 Fe_3C

hence one part carbon produces $\frac{180}{12} = 15$ parts Fe_3C or cementite.

of pearlite in hyper-eutectoid steel, the percentage of carbon in the steel should be substituted for C in the formula:

$$P = \frac{800 - 120\,C}{7}$$

and the balance of the steel will be made up of free cementite ($Cm = 100 - P$).

Taking, for instance, a steel containing 0.50 per cent. carbon, its structural composition will be:

$120 \times 0.50 = 60$ per cent. pearlite, and
$100 - 60 = 40$ per cent. ferrite.

If a steel contains 1.25 per cent. carbon the resulting percentage of pearlite will be

$$\frac{800 - 120 \times 1.25}{7},$$

or nearly 93 per cent., and the free cementite (Cm), $100 - 93 = 7$ per cent.

CHEMICAL VS. STRUCTURAL COMPOSITION.

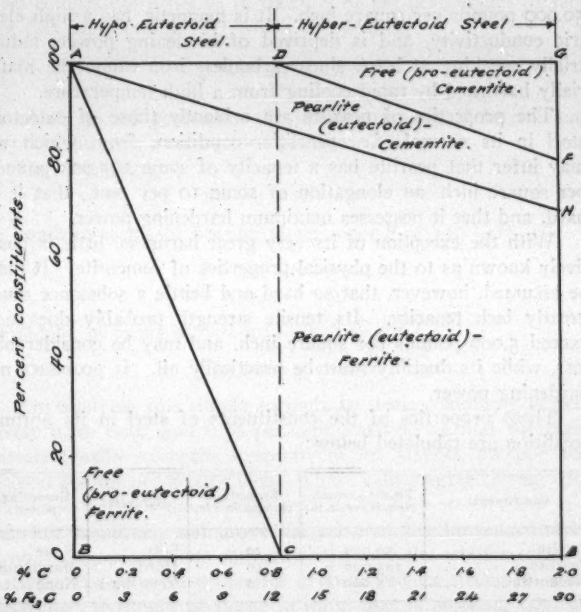
Disregarding the existence of impurities, the ultimate analysis of steel reveals the presence of so much carbon and so much iron. The proximate chemical analysis of steel reveals (in steel slowly cooled from a high temperature) the presence of so much iron and so much carbide of iron, Fe_3C. In a similar way we may consider two different structural compositions, an ultimate and a proximate one. The ultimate structural composition reveals the presence of so much total ferrite and so much total cementite, while the proximate structural composition informs us of the percentages of pearlite, free ferrite, and free cementite in the steel. It will be evident that the chemical proximate composition is identical to the ultimate structural composition, the names of the constituents only being different—iron and carbide in the first case, ferrite and cementite in the latter.

These various compositions are tabulated below:

		Constituents.
Chemical Composition	ultimate: Fe	C
	proximate: Fe	Fe_3C
Structural Composition	ultimate: total ferrite	total cementite
	proximate: pearlite	free ferrite, free cementite.

It is apparent that the proximate structural composition affords more valuable information than is obtainable through the other three kinds of analyses, for not only does it indicate the chemical nature of the proximate constituents but also their structural association and occurrence, upon which depend, to a very great extent, the physical properties of steel.

FIG. 1.



The structural composition, both ultimate and proximate, of slowly cooled steel is shown diagrammatically in Fig. 1, which will be readily understood. *ABC* represents the free ferrite in hypo-eutectoid steel, *ACD* the pearlite in hypo-eutectoid steel, *DCEF* the pearlite in hyper-eutectoid steel, *DFG* the free cementite in hyper-eutectoid steel, *ABEH* the total ferrite in any steel, *AHG* the total cementite in any steel, *ACEH* the pearlite-ferrite in any steel, and *AHFD* the pearlite cementite in any steel.

PHYSICAL PROPERTIES OF THE STRUCTURAL CONSTITUENTS OF STEEL.

It will be evident that the physical properties of commercial ferrite must resemble closely those of wrought iron and of very low carbon steel. Ferrite, therefore, is very soft, very ductile, and relatively weak, having a ductility corresponding to an elongation of at least 40 per cent. and a tensile strength of some 50,000 pounds per square inch. It is magnetic, has a high electric conductivity, and is deprived of hardening power, industrially speaking at least, since carbonless iron cannot be materially hardened by rapid cooling from a high temperature.

The properties of pearlite are evidently those of eutectoid steel in its normal—*i.e.*, pearlitic—condition, from which we may infer that pearlite has a tenacity of some 125,000 pounds per square inch, an elongation of some 10 per cent., that it is hard, and that it possesses maximum hardening power.

With the exception of its very great hardness, little is positively known as to the physical properties of cementite. It may be assumed, however, that so hard and brittle a substance must greatly lack tenacity. Its tensile strength probably does not exceed 5,000 pounds per square inch, and may be considerably less, while its ductility must be practically nil. It possesses no hardening power.

These properties of the constituents of steel in its normal condition are tabulated below:

Constituents	Tensile strength, pounds per sq. in.	Elongation, per cent in 2 in.	Hardness	Hardening power
Ferrite	50,000 ±	40 ±	Soft	None
Pearlite	125,000 ±	10 ±	Hard	Maximum
Cementite	5,000 (?)	0	Very hard	None

TENACITY OF STEEL VS. ITS STRUCTURAL COMPOSITION.

Knowing the physical properties of the three constituents of steel, it should be possible to foretell with some degree of accuracy the physical properties of any steel of known structural composition, on the reasonable assumption that these constituents impart to the steel their own physical properties in a degree proportional to the amounts in which they are present. The

properties of steel made up, for instance, of 50 per cent. ferrite and 50 per cent. pearlite should be the means of the properties of ferrite and of pearlite. Let us assume such reasoning to be correct, and let us apply it to the tensile strength, first of hypo-eutectoid steel and then of hyper-eutectoid steel.

The tensile strength (T) of any hypo-eutectoid steel will be expressed by the following formula in function of its structural composition; that is, in function of the percentages of ferrite (F) and pearlite (P) which it contains:

$$T = \frac{50{,}000\ F + 125{,}000\ P}{100}$$

in which 50,000 represents the tensile strength of ferrite and 125,000 the tensile strength of pearlite.

Or simplifying:

$$T = 500\ F + 1250\ P$$

or again in terms of pearlite alone, since $F = 100 - P$

$$T = 500\ (100 - P) + 1250\ P$$
$$\text{or } T = 50{,}000 + 750\ P$$

or finally, in terms of carbon, since $P = 120\ C$

$$T = 50{,}000 + 90{,}000\ C$$

On applying this simple formula to steels containing respectively 0.10, 0.25, and 0.50 per cent. carbon, we find for these metals tensile strengths, respectively, of 59,000, 72,500, and 95,000 pounds per square inch. These values agree closely with our knowledge of the average tenacity of such steels when in a pearlitic condition, and prove the value of the formula derived from the considerations outlined above as to the relation existing between the physical properties of steel and its structural composition. It should be borne in mind that in working out this formula it has been assumed that pearlite contains 0.834 per cent. carbon.

The values obtained for various eutectoid steel should be accurate only for steel in its pearlitic condition. It should be noted, however, that steels forged and finished at a fairly high temperature are practically in this condition, so that the formula may be used, and fair results expected, to calculate the tensile

strength of such hot forged steels. If the steel be forged until its temperature is quite low, and especially if it be cold worked, it is well known that its tensile strength is generally increased. Neither can the formula be used, of course, in the case of hardened steel or of steel castings. It may, however, be applied to steel castings which have been properly annealed, when the tensile strength may be brought up to the level of steel forgings finished fairly hot.

Again, the formula is of value only in case of commercial steels containing the usual proportions of impurities, especially of manganese. It applies only to steels in which the percentage of manganese varies roughly with the carbon content from some 0.20 to 0.80 per cent. The presence of a larger proportion of manganese would increase the tenacity materially.

Passing to the tensile strength of hyper-eutectoid steel, our ignorance as to the tenacity of cementite does not permit the writing of a formula with the same degree of confidence. Let us assume, tentatively, however, that cementite has a tensile strength of 5,000 pounds per square inch, and then proceed as we did in the case of hypo-eutectoid steel.

The tensile strength of any hyper-eutectoid steel may be expressed by the following formula in terms of the percentages of pearlite (P) and cementite (Cm) which it contains:

$$T = \frac{125{,}000\,P + 5000\,Cm}{100}$$

or simplifying

$$T = 1250\,P + 50\,Cm$$

or, in terms of pearlite only, since $Cm = 100 - P$,

$$T = 1250\,P + 100\,(50 - P)$$
$$T = 5000 + 1200\,P$$

or since, as previously shown,

$$P = \frac{800 - 120\,C}{7}$$

$$T = 5000 + 1200\,\frac{800 - 120\,C}{7}$$

or simplifying

$$T = \frac{995{,}000 - 144{,}000\,C}{7}$$

or approximately $T = 142{,}000 - 20{,}600\,C$.

Applying this formula to steels containing, respectively, 1.25 and 1.50 per cent. carbon, we find for their respective tensile strength 116,250 and 111,100 per square inch, which are fair values for the average tenacity of pearlitic steels of those degrees of carburization.

STEEL OF MAXIMUM STRENGTH.

From the preceding considerations it seems evident that eutectoid steel must possess maximum tensile strength, since the influence of the presence of ever so small an amount of free ferrite in hypo-eutectoid steel or of free cementite in hyper-eutectoid steel must necessarily be a weakening one, because of the relative weakness of free ferrite and free cementite as compared to the strength of pearlite. By most writers, on the other hand, steel of maximum tenacity is often stated to contain in the vicinity of 1 per cent. carbon—that is, to be slightly hyper-eutectoid.

It is not clear, however, that the results upon which the statement is based were obtained in testing steel in its *pearlitic condition*. On the contrary, it seems probable that a large number of the steels tested were in a sorbitic rather than in a pearlitic condition because of relatively quick cooling through the critical range. And, while it appears that pearlitic steel must have its maximum tenacity when composed entirely of pearlite, it may well be that when in a sorbitic condition maximum strength corresponds to a higher degree of carburization—*i.e.*, 1 per cent.—because sorbite may contain, and indeed often does contain, more carbon than pearlite. Indeed, the cases on record show that when the steels were made pearlitic through very slow cooling maximum tenacity corresponds closely to the eutectoid composition. Arnold, for instance, tested a series of very pure carbon steel and after slow cooling in the furnace from 1,000° C. he found a very sharp maximum in the tenacity corresponding to 0.89 per cent. carbon. On cooling these same steels in air, on the contrary, and therefore making them sorbitic, maximum tenacity corresponded to 1.20 per cent. carbon. Harbord likewise ascertained the tenacity of very pure steels, and found that after slow cooling (in the furnace) from 900°

C. the maximum tenacity corresponded to 0.947 per cent. carbon.

DUCTILITY OF STEEL VS. ITS STRUCTURAL COMPOSITION.

From the known ductility, as expressed by its elongation under tension, of ferrite and the known elongation of pearlite, respectively 40 and 10 per cent. in two inches, it should be possible to work out a formula expressing the ductility of any hypo-eutectoid steel in the annealed (pearlitic) condition. In terms of ferrite and pearlite the ductility should be

$$D = \frac{40\,F + 10\,P}{100}$$

or simplifying

$$D = .4\,F \times .1\,P$$

or, in terms of pearlite alone, since $F = 100 - P$,

$$D = .4\,(100\,P) \times .1\,P = 40 - .3\,P$$

and since $P = 120\,C$, the ductility in terms of carbon will be

$$D = 40 - 36\,C$$

Pearlitic steels, for instance, containing 0.25 and 0.50 per cent. carbon should have elongations, respectively, of 31 and 22 per cent.

REDUCTION OF AREA VS. STRUCTURAL COMPOSITION OF STEEL.

In a similar way we may calculate the reduction of area of any slowly cooled (*i.e.*, pearlitic) hypo-eutectoid steel, on the assumption that pearlite has a reduction of area of 15 per cent. and ferrite a reduction of 60 per cent. The reduction of any steel will then be, in terms of ferrite and pearlite:

$$R = \frac{60\,F + 15\,P}{100} = .60\,F + .15\,P$$

or, in terms of pearlite alone, since $F = 100 - P$,

$$R = .60\ (100 - P) + .15\ P = 60 - .45\,P;$$

or, finally, in terms of carbon, since $P = 120\,C$,

$$R = 60 - 54\,C.$$

Pearlitic steels, for instance, containing 0.25 and 0.50 per cent. carbon should have reductions of area, respectively, of 46.5 and 33 per cent.

NOTES FROM THE BUREAU OF STANDARDS.

CIRCULAR ON REGULATIONS FOR ILLUMINATING GAS.

THE National Bureau of Standards has just issued a circular entitled "State and Municipal Regulations for the Quality, Distribution, and Testing of Illuminating Gas." This circular (133 pages, uniform in style with other Bureau circulars) has been prepared after conference and correspondence with a large number of gas engineers and inspectors; and it represents, as nearly as possible, the average opinion of many men active in the field of gas manufacture and gas testing.

Part I of the circular gives a summary of the municipal gas ordinances now operative, and proposes an ordinance largely compiled from the best ordinance requirements now in force.

Part II treats similarly of State control of gas companies, and proposes technical rules for State regulations.

Part III quotes a few ordinances typical of those recently enacted, and gives the main portions of State gas laws now in force affecting gas quality, pressure, and meter accuracy.

The circular does not concern itself with financial regulations of gas companies, nor does it include any discussion of the comparative value of various methods of works management. It deals mainly with the candlepower, heating value, purity, and pressure of the gas and gas-meter testing.

The present publication has grown out of the investigation of the methods and standards employed in gas photometry and gas calorimetry, undertaken by the Bureau three years ago. A second circular on the methods of testing employed for official inspection work is now being prepared. Although it cannot be expected that the regulations for or methods of gas testing will ever be entirely uniform throughout the country, it is believed that if the results of a comprehensive investigation of the subject are published, a greater uniformity of method, and in some cases more accurate measurements, will result

The attitude of the Bureau of Standards is entirely advisory, and its intention is to place in the hands of the technical and general public an impartial and, as nearly as may be, an accurate

summary of the facts which must be considered in connection with the fixing of standards of quality and the testing of illuminating gas.

Revision of the circular from time to time is contemplated in order to amend the recommendations as to the requirements to adapt it to new developments in the gas industry.

Copies may be obtained free of charge by addressing The Director, Bureau of Standards, Washington, D. C.

CORRECTION.

SURFACE COMBUSTION (W. A. Bone).

Lines 11 and 12, page 107 of the article appearing in February, 1912, issue, should read as follows:

"activity" of the surface may be greatly stimulated by previous contact with the combustible gas, and, conversely, may be diminished by previous contact with oxygen.

American Association of Refrigeration.—The annual meeting of the association will be held in Washington, D. C., on May 6th and 7th. The sessions are to be held in the New Willard Hotel, and at the Bureau of Standards. A detailed programme is in preparation. Final action will also be taken at this meeting in reference to the plans for the Third International Congress of Refrigeration.

Settlement of the Potash Dispute. (*Board of Trade Jour.*, Feb. 8, 1912.)—The settlement of the difference between the United States and German Governments arising out of the application of the German law of May, 1910, as to the disposal of potash salts, provides for the withdrawal of all suits in United States courts involving liability for the payment of the potash tax levied by Germany; for the assignment to the German Potash Syndicate of United States contracts with the independent mines; for new contracts with the Syndicate covering the whole of the United States potash requirements on a price basis ($32.40 per ton) practically the same as that prevailing before the low price contracts were obtained from the independent mines; and for the re-entry of the independent mines into the Syndicate.

FRANKLIN INSTITUTE

(Proceedings of the Stated Meeting held Wednesday, April 17, 1912.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 17, 1912.

MR. JOHN C. TRAUTWINE, JR., *in the Chair.*

Additions to membership since last report, 3.

The Chairman announced a vacancy on the Board of Managers. Dr. George D. Rosengarten was nominated and the Secretary directed to cast the ballot of the meeting for the nominee.

The following proposed amendment to the By-Laws was presented for first reading:

> Article XIII, Section 1, to be amended by striking out "and" in 3d line, and adding "June" before "July" in 3d line; and adding "and September" after "August" in 4th line, so that by-law, after amendment, will read as follows, the new matter being in italics:
>
> ARTICLE XIII.
>
> SECTION 1.—"The Institute shall hold stated meetings on the third Wednesday of each month, except in *June*, July, August, *and September*. That on the third Wednesday in January of each year shall be the annual meeting."

The Chairman then introduced Mr. George R. Henderson, Consulting Engineer of the Baldwin Locomotive Works, who presented the paper of the evening, entitled "Recent Development of the Locomotive."

The speaker described the numerous improvements and changes which have been made in locomotives during the past several years, referring especially to their size and power and improved details of construction.

Numerous lantern slides of the various types of engines were shown, and the modifications which have been made from time to time were pointed out.

A brief discussion followed the paper, in which Messrs. Eaton, Wright, Warner, and others participated.

On motion, duly seconded, the thanks of the meeting were extended to the speaker.

R. B. OWENS,
Secretary.

ANNUAL REPORT OF THE DIRECTOR OF THE SCHOOL OF MECHANIC ARTS OF THE FRANKLIN INSTITUTE FOR THE SEASON 1911-1912.

The School of Mechanic Arts has shown, this season, a marked advance in every direction—in the number of students enrolled, in the regularity of their attendance, in the seriousness of their work, in the appreciation of the opportunities presented to them, and in the results they have accomplished.

The total number of students registered this year was 292. Of these 168 were enrolled in the Department of Drawing, 68 in the Department of Mathematics, 34 in the Department of Mechanics, and 22 in the School of Naval Architecture. The number of students registered last year was 232.

The schedule adopted in 1909 having been found to meet the requirements of the students to an extent only limited by the present capacity of the school buildings, the work was again carried out on the lines then laid down. That a continuance of the plan being followed is fully justified is shown in the results obtained this year.

The success of the season has been due to the co-operation of my associates in the faculty: Messrs. Wm. E. Bullock, H. C. Towle, Clement Remington, H. P. Tyson, I. P. Pedrick, R. R. Umstead, W. W. Twining, F. H. Lobb, and A. T. Klein, to whom I desire to express my appreciation.

WM. H. THORNE, *Director.*

The following students having satisfactorily completed a two years' course are awarded

CERTIFICATES.

MECHANICAL DRAWING.

Raymond West Betts
Edward G. Carpenter
Clayton Essex
Clarence Gaunt
Leonard Gutekunst
Fred Gutekunst
George C. Gutekunst
Roland G. Heppard
John A. McDowell
William F. Meixner
Malcolm V. D. Remington
William Rhodes
Waldemar Rival
Juan Tarin Sanchez

ARCHITECTURAL DRAWING.

William Bardsley
Dominic Caruso
Eugene Dear
Merritt Dodd
Ara S. Pennewell

FREEHAND DRAWING AND WATER COLOR.

Harry E. Donohue
Theodore A. Nicholson
H. Walter Stevenson
John Zimmerman

MATHEMATICS.

Charles F. Carman
Arthur C. Chancellor
Jeremiah Driscoll
Albert B. Kurz
Benjamin F. Lees
Harry L. Lees
William Meinel
Leon F. Roemer

MECHANICS.

Robert J. Heiserman — Warren M. Stone

NAVAL ARCHITECTURE.

LeRoy V. Calhoun — Ambrose H. McDade
S. B. Furstenau — Frank H. Sauer
Fred J. Howard — Joseph W. Thompson

HONORABLE MENTION.

For their interest, industry and success during the season, the following students receive certificates of Honorable Mention:

DEPARTMENT OF DRAWING.

Junior Mechanical Class.

Winter Term.

Clifford Bach — Benjamin Halpern
Leo J. Botteicher — James R. Leacock
Roger D. Eastlake — R. Lehman Margerum
Karl Fichtner — George L. McGuigan
Harry Froehlick — Lyle L. Quail
Harold T. Hall — Louis C. Schubert
William J. Wear, Jr.

Spring Term.

John B. Craig — Benjamin Bernhard Lubarsky
Fred Reed

Intermediate Mechanical Class.

Winter Term.

Edward C. W. Craven — Herbert Jayes
John W. Cunningham — John D. Masterson
Robert N. Hudson — John A. McDowell
Juan Tarin Sanchez

Spring Term.

Norman A. Beetham — James R. Leacock
Fred J. Benz — R. Lehman Margerum
Charles F. Carman — David Paul Masserott
Jonathan Cleaver — Thomas Morrissey
John W. Cunningham — Lyle L. Quail
Norman Derby — George P. Read
Rowland G. Dietz — Louis C. Schubert
Karl Fichtner — William J. Wear, Jr.
Benjamin Halpern — John Weber

Senior Mechanical Class.

Winter Term.

Clayton Essex — Malcolm V. D. Remington
Clarence Gaunt — William Rhodes
Leonard Gutekunst — Waldemar Rival

Spring Term.

Edward C. W. Craven
Fred Gutekunst
Malcolm V. D. Remington
Juan Tarin Sanchez
Herbert Jayes

Architectural Class.

Winter Term.

William Bardsley
John T. Bauer
Merritt Dodd
Harry T. Godfrey
Timothy McCarthy
J. Albert Raith
Edgar Worley.

Spring Term.

William Bardsley
Dominic Caruso
Harry T. Godfrey
George Howard Kelly
Frederick H. Stigale
Robert E. Swiler
Walter T. Teichman

Freehand Class.

Winter Term.

Theodore A. Nicholson
H. Walter Stevenson
John Zimmerman

Spring Term.

William H. Cameron
Sophie Colles
H. Walter Stevenson
Theodore A. Nicholson

DEPARTMENT OF MATHEMATICS.

Algebra.

Winter Term.

Howard G. Balz
Otto Roeder
August G. Schweizer
Richard Warren

Spring Term.

Howard G. Balz
Benjamin Halpern
Richard M. Warren
Louis G. Zelson

Plane Geometry.

Winter Term.

C. H. Becker
Earle G. Hall
Albert B. Kurz
William Meinel
William Rhodes

Trigonometry.

Spring Term.

Earle G. Hall
Albert B. Kurz
William Meinel
William Rhodes
Leon F. Roemer
Ernest Steel

DEPARTMENT OF MECHANICS.

Applied Mechanics and Strength of Materials.

Winter Term.

Joseph M. Barnes — John L. Dugan
Clarence E. Bullinger — Samuel E. Hart

Machine Design.

Spring Term.

Clarence E. Bullinger — Milton G. Cundey
Eaton Burrows.

Structural Design.

Spring Term.

Robert J. Heiserman — Carroll Shaw*
Norman S. Snyder.

SCHOOL OF NAVAL ARCHITECTURE.

Winter Term.

Junior Year.

Edwin Baker — Samuel H. Carter
Richard L. Burke — Asbjoin Drangeid

Senior Year.

LeRoy V. Calhoun — Joseph W. Thompson

Spring Term.

Junior Year.

Richard L. Burke — Samuel H. Carter
Asbjoin Drangeid — M. P. Gregg

Senior Year.

Joseph W. Thompson

In the Department of Drawing, Scholarships from the B. H. Bartol Fund were awarded in the Winter Term to the following students, who now receive Bartol certificates:

Merritt Dodd — Herbert Jayes
Clayton Essex — R. Lehman Margerum
Harry T. Godfrey — Lyle L. Quail
John Zimmerman

The following students are awarded Scholarships in the Spring Term and now receive Bartol certificates:

Sophie Colles — Fred Reed
John W. Cunningham — Malcolm V. D. Remington
James R. Leacock — Frederick H. Stigale
Lyle L. Quail — Walter T. Teichman

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of Stated Meeting held Wednesday, April 3, 1912.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 3, 1912.

DR. GEORGE A. HOADLEY *in the Chair.*

The following report was presented for final action:
No. 2511.—Karn's Tunneling Machine. Longstreth Award. Adopted.
The following reports were presented for first reading:
No. 2383.—Downe's Asbestos-covered Magnet Wire.
No. 2508.—Turner's Air-Brake Improvements.
No. 2514.—Kennicott Water Weigher.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—A joint meeting of the Section of Physics and Chemistry and the Philadelphia Section of the American Chemical Society was held in the Hall of the Institute on Thursday, March 28, 1912, at 8 o'clock P.M., with Dr. Harry F. Keller in the chair.

One hundred and forty members and visitors were present.

The reading of the minutes was dispensed with.

Dr. R. B. Moore, of Washington, D. C., delivered a lecture on "The History, Properties, Preparation, and Uses of the Rare Gases." The rare gases of the atmosphere and the emanations of the radio-active elements were discussed. The lecture was accompanied by experiments illustrating the preparation of the rare gases from the air, the spectrum of each gas in the pure state, and the detection of emanation by means of the electroscope.

A vote of thanks was tendered Dr. Moore, and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Mechanical and Engineering Section.—A meeting of the Section was held on Thursday evening, April 4, 1912, at 8 o'clock. Mr. George R. Henderson, Chairman.

The minutes of the previous meeting were approved as printed in the JOURNAL.

The Chairman then introduced Mr. Walter V. Turner, Chief Engineer of the Westinghouse Air-Brake Company, who presented an interesting communication on "Electropneumatics as Applied to Train Control."

The recent advances in the use of electricity as an adjunct to the air-brake were fully described, and the various details of modern air-brake equipment and its control were shown by means of numerous lantern slides.

The thanks of the meeting were extended to Mr. Turner.

Adjourned.

R. B. OWENS,
Secretary.

Section of Mining and Metallurgy.—A special meeting of the Section was held on Tuesday, April 9, 1912. Mr. Louis E. Levy in the chair.

A communication on natural gas was presented by Mr. I. N. Knapp, Consulting Engineer of Philadelphia.

After an historical sketch of the occurrence of natural gas in various parts of the world and its surface indications, the several theories of its origin were considered. The geological features of natural gas regions were pointed out, and statistics of production for various periods were presented. The subject was illustrated by many lantern slides taken from original photographs made by the speaker.

The Chairman conveyed the thanks of the Section to Mr. Knapp, and the meeting adjourned.

R. B. OWENS,
Secretary.

Section of Physics and Chemistry.—The stated meeting of the Section was held in the Hall of the Institute on Thursday, April 11, 1912, at 8 P.M., with Dr. Robert H. Bradbury, President of the Section, in the chair. One hundred members and visitors were present. The minutes of the meetings of January 4th and March 28th were approved as read.

Dr. Harry F. Keller, Professor of Chemistry and Head of the Department of Science in the Central High School of Philadelphia, delivered an address on "Platinum," in which he discussed the history, geology, mode of occurrence, extraction, purification, metallurgy, properties, and uses of that metal. Statistics concerning the production and value of platinums were given, and certain substitutes for platinum were described.

The lecture was illustrated by means of lantern slides, and of specimens of native and refined platinum, sperrylite, the native arsenide of platinum, platinum salts, and platinum-clad nickel-steel wire.

A vote of thanks was extended to Dr. Keller, the paper was discussed, and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

MEMBERSHIP NOTES.

Elections to Membership.

RESIDENT.

MR. JOSEPH HARRISON EASTWICK, 6306 Overbrook Avenue, Overbrook, Pa.

NON-RESIDENT.

MR. HARROLD HIBBERT, 400 West Ninth Street, Wilmington, Del.

ASSOCIATE.

MR. RAYMOND A. BLOCK, 2731 Cambridge Street, Philadelphia, Pa.

Changes of Address.

MR. CHARLES A. LINDSTROM, 138 Stratford Avenue, Pittsburgh, E. E., Pa.
MR. JOS. B. ROHRMAN, Hammonton, N. J.
MR. HARRISON D. STRATTON, 4301 Walnut Street, Philadelphia, Pa.
MR. W. S. ELLIS, Fox Hill Farm, Bryn Mawr P. O., Pa.
MR. E. P. BORDEN, 421 Chestnut Street, Philadelphia, Pa.
MR. WALTER T. LEE, 308 Rex Avenue, Chestnut Hill, Pa.
MR. CHARLES J. RUSSEL, 4522 Frankford Avenue, Philadelphia, Pa.
MR. F. E. HAYES, JR., 900 Lincoln Building, Louisville, Ky.

NECROLOGY.

Harrison White Biddle, Esq., was born in Washington, D. C., May 16, 1864, and died in Philadelphia, March 30, 1912.

Mr. Biddle was educated at St. Paul's School, Concord, N. H., and the University of Pennsylvania, receiving the degree of Bachelor of Arts from the latter institution.

He was a member of numerous clubs and other organizations.

Mr. John Wiegand, 1702 North Twenty-first Street, Philadelphia, Pa.

Mr. Albert Shoenhut, Adams and Sepviva Streets, Philadelphia, Pa.

LIBRARY NOTES.

Purchases.

HAHNS, M. P. M.—Beschreibung mechanischer Kunstwerke, 1774.
THOMSON, SIR WILLIAM.—Mathematical and Physical Papers, vols. 5 and 6, 1911.
KNOTT, C. G.—Life and Scientific Work of Peter Guthrie Tait, 1911.
RICHARDSON, A.—The Evolution of the Parsons Steam Turbine, 1911.
HARBORD, F. W., and J. W. HALL.—The Metallurgy of Steel, 2 volumes, 1911.
WEIMARN, P. P. VON—Gründzuge der Dispersoidchemie, 1911.
BOYD, J. E.—Strength of Materials, 1911.
FOWLER, G. L.—Forney's Catechism of the Locomotive, 1911.
PRELINI, C.—Dredges and Dredging, 1911.
MORROW, J.—Steam Turbine Design, 1911.
PARKHURST, F. A.—Applied Methods of Scientific Management, 1912.
BLANCHARD, A. H., and H. B. DROWNE—Highway Engineering, 1911.
HECK, R. C. H.—The Steam Engine and Turbine, 1911.

LOEWENSTEIN, L. C., and C. P. CRISSEY—Centrifugal Pumps, 1911.
BREARLEY, H.—The Heat Treatment of Tool Steel, 1911.
MEIER, K.—Mechanics of Heating and Ventilating, 1912.
BIRD, R. M., ed.—Modern Science Reader, 1911.
EARLE, S. C.—The Theory and Practice of Technical Writing, 1911.
TIEMANN, H. P.—Iron and Steel, 1910.
BASKERVILLE, C., ed.—Municipal Chemistry, 1911.

Gifts.

Graphite, vol. 13, 1911. Jersey City, 1911. (From Joseph Dixon Crucible Company.)

Drexel Institute, Year-Book of the Departments and Courses of Instruction, 1911–12. Philadelphia, n. d. (From the Institute.)

Temple University, Catalogue 1912–13. Philadelphia, 1912. (From the University.)

U. S. Interstate Commerce Commission, 23d Annual Report of the Statistics of Railways in the United States, for the year ending June 30, 1910. Washington, D. C., 1912. (From the Commission.)

Piano and Organ Purchaser's Guide for 1912, compiled by John C. Freund. New York, 1912. (From the Music Trades Company.)

Philadelphia College of Physicians, Transactions, vol. 33, 1911. Philadelphia, 1911. (From the College.)

Societe des Ingenieurs Civils de France, Annuaire de 1912. Paris, 1912. (From the Society.)

Societe de Physique et D'Historie Naturelle, Geneve, Compte Rendu des Seances, vol. 38, 1911. Geneve, 1912. (From the Society.)

Michigan State Board of Agriculture, 50th Annual Report, including 24th Annual Report of the Experiment Station, 1910–1911. Lansing, 1911. (From the Experiment Station.)

Institution of Naval Architects, Transactions, vol. 53, parts 1 and 2, 1911. London, 1911. (From the Institution.)

Boiler Explosions Act 1882 and 1890, 28th Annual Report upon the working of the act, 1909–1910. London, 1911. (From the Manchester Steam Users' Association.)

Canada Department of Trade and Commerce, Report. Part 3, Canadian Trade with Foreign Countries, for year ended March 31, 1911. Ottawa, 1912. (From the Department.)

Harvard University Official Register. Reports of the President and the Treasurer, 1910–1911. Cambridge, 1912. (From the University.)

Canada Experimental Farms, Reports for year ending March 31, 1911. Ottawa, 1911. (From the Department of Agriculture.)

New York Public Service Commission, Proceedings, vol. 6, 1911. New York, n. d. (From the Commission.)

Rose Polytechnic Institute, 30th Annual Catalogue, 1911–1912. Terre Haute, n. d. (From the Institute.)

Great Britain Labour Department, Report on Trade Unions in 1908–1910. London, 1912. (From the Department.)

McGill University, Annual Report of the Governors, Principal and Fellows for the year 1910–1911. Montreal, n. d. (From the University.)

Canadian Society of Civil Engineers, Charter, By-Laws and List of Members, 1912. Montreal, n. d. (From the Society.)

U. S. Department of Commerce and Labor, Bureau of Statistics, Statistical Abstract of the United States, No. 34, 1911. Washington, 1912. (From the Bureau.)

Society of Naval Architects and Marine Engineers, Transactions, 1911. Washington, 1912. (From the Society.)

Ontario Department of Agriculture, Report of Fruit Branch, 1911. Toronto, 1911. (From the Department.)

BOOK NOTICES.

ENGINEERING AS A VOCATION. By Ernest McCullough, C.E. 201 pages, 8vo. New York, David Williams Co., 1911. Price, in cloth, $1.

This work, issued in 1911, as its title indicates, treats in a general way of the qualifications, preparation for and performance of the duties of engineers in the numerous branches of their profession, now so greatly diversified. The author, although a civil and consulting engineer, gives good general advice and suggestions covering all the differentiations of the science, and, after quoting the origin of the name and its definitions, proceeds in the first chapters to define the man and his evolution, followed by the ancient state of the art briefly brought to date.

In the third chapter there may be room for honest differences of opinion as to the historic development of the profession. On page 20 it is stated: "Hero of Alexandria is styled the first engineer recorded in history," and yet Hero's period was about 284–221 B. C., while the "Calendar of Invention and Discovery" states that Archimedes was known as "The Father of Civil Engineering"—born at Syracuse about 287 B. C., died 212 B. C., and therefore contemporaneous with Hero, and quite as famous. In 325 Aristotle first mentioned diving bells, and five years later wrote his Mathematics.

But, if one is seeking for the origin of engineering, why start at Hero and ignore the great works of the Chaldæans, who, in A.M. 1775, built the great Tower of Babel, 120 years after the Deluge, and erected the great cities of Nineveh and Babylon, with their immense irrigation works, canals, Hanging Gardens and palaces under Nimrod, Belus and Semiramis, or why not revert to the Pyramids of Egypt, which have weathered more than 4000 years? Or, if for the artificers in metal, why not begin with Tubal Cain, "an instructor in every artificer in brass and iron" (A.M. 126), or to Noah as the greatest of naval architects?

Again, in attempting to establish the origin of bridge building as a science, mention is made of Squire Whipple's "Practical Treatise" of 1847 and "Haupt (On Bridge Construction) in 1851," but the latter engineer

was experimenting years before he could find a publisher willing to risk so technical a work, and in 1840 he "discovered a method of Representing Strains by Geometrical Solids; Deflections by Parabolic Areas; and the Variable Pressures at Various Parts of Beams by Corresponding Ordinates of Plane Curves," and the same year patented his Improved Lattice Truss.

The author's definition of the electrical engineer is unique, since he characterizes him as "being a cross between a physicist and a mechanical engineer, having a marked strain of conceit common to youth; the electrical engineer being comparatively an infant." Possibly this new "strain" (of conceit) may be responsible for some of the bold freaks of all engineers ending in failures due to the "fatigue of metals" or low "limits of elasticity." It is, however, an element to be considered in the man as an engineer.

Of waterways and docks the author states the rules have not much changed in the past century, and he appears to believe that "navigation canals have everywhere given way to railways, except where interested agitation keeps alive a public interest in old-fashioned things." "A few are kept up at enormous expense to supposedly act as a deterrent upon railway rates, etc." Those opinions are sufficiently answered by the views of some of the greatest railway presidents and managers of to-day, as expressed at the meetings of the National Waterways Congress, where their great practical utility is amply asserted. This vital subject cannot be discussed in this connection.

The author incidentally refers to the influence of politics in the construction of highways as impairing the efficiency of the work, which many engineers deplore.

Sixty pages are given to an analysis of the methods available for acquiring an education covering a period of sixteen to eighteen years in some technical schools for developing specialists, or in the correspondence schools for self-trained men, with notes on the curriculum and valuable hints as to standards and instructors.

Another chapter is devoted to the Home Study Courses for men who wish to increase their earning capacity by night work, either alone or in classes, at some Y. M. C. A. or other institution, but the author prefers the personal contact of a real live engineer to the correspondence methods. Certain reference books are given with their prices.

This is followed by diagrams of graphical records of labor costs per unit of product and the economics of shop practice, with the money value of a technical training, accompanied by citations from special cases by way of illustration.

Chapter V treats of "How to Hunt and Hold a Job," giving percentages of men in some of the subdivisions of their profession, the largest, 20.2 per cent., being consulting engineers. It also treats of the tendency to subject engineers to legislative enactments, and how it may be misused to hold men down in subordinate positions.

The question of pay and occupation is practically presented by the author, who has been subjected to the constant changes incidental to the transient character of his engagements, and this fact tends to discredit a man

in the eyes of his would-be employer, while increasing his efficiency by varied experience. Reference is made to the American Technical Association, organized in Chicago to aid in securing positions, on a benevolent basis, with small fees for membership, as being a good medium. The practice of discharging the older and more experienced men at an early age to make room for the cheaper graduates is deprecated, even in the military service, but in this latter case the Government provides a pension, while the civilian is compelled to shift for himself. These are but a few of the many good points which are well worthy of consideration by a young man looking for a choice of professions. The author suggests that self-tutored men should never buy a book dated prior to 1895, so that his book is not yet "outlawed" and will prove interesting as well as instructive to the neophyte.

It is entertaining, suggestive, and based on practical experience.

LEWIS M. HAUPT.

COCOA AND CHOCOLATE. By R. Whymper. Published by P. Blakiston, Philadelphia. 327 pages (16 x 24.5 cm.). Price, $5.

This book is a complete account of the subject, covering the agriculture of "*Theobroma cocoa*," the fermentation of the beans, their preparation for market, and the manufacture of chocolates, including special varieties, like milk chocolates and soluble cocoas. The last four chapters (70 pages) are devoted to an elaborate critical survey of the microscopical and chemical examination of the beans and the products made from them.

The word chocolate is of Aztec origin, and the product was introduced into Europe by Cortez when he returned, in 1528, from the conquest of Mexico. It is of interest to learn that while, at present, the consumption of coffee remains almost stationary, that of cocoa and chocolate increases by leaps and bounds. Thus, in Germany, between 1886 and 1898, the consumption of coffee increased 24 per cent., while in the same time the consumption of cocoa and chocolate increased 330 per cent.

So far as adulteration is concerned, the author leans decidedly to the view that the standard brands of cocoa products now on the market are pure and carefully made, though this was not always the case. Thus, Hassall, in 1876, claims to have examined chocolate powders which consisted of stale sea-biscuit, coarse flour, and tallow, flavored with a decoction of cocoa shells, sweetened with treacle, and colored with brick dust, ferric oxide, cinnabar, or even red lead. One cannot be too thankful that the activity of the food-analyst has made it impossible, at present, to market such diabolical mixtures. However, certain aspects, especially of the production of "soluble cocoas," would probably repay the attention of the food chemist. Thus, on page 107, we read:

"To 100 pounds of cocoa paste are added 3 pounds caustic potash, dissolved in 1 gallon of water, the mixture thoroughly kneaded," etc. While it is possible that most of the potassium hydroxide is removed, with the fat, in the hydraulic compression which follows, yet the use of caustic alkalies in such quantities in a food product seems hardly fair to the dyspeptics and invalids for whom the material is especially intended.

An interesting phenomenon, mentioned on page 129, is the "fatigue

of chocolate." By this is meant the fact that chocolate, after constant consecutive refining, passes into a dry, powdery state, from which it will not recover without the addition of more cocoa butter. This matter would seem to deserve some elucidation from the colloid chemist. The book gives the impression that the great industry of cocoa-products rests upon purely empirical foundations, and, like the leather industry, still awaits the transformation which follows a scientific study of methods. This remark is not to be construed as a criticism of the book, which is clearly written and evidently the result of a thorough knowledge of the subject. The work is well illustrated with original photographs, and the presswork is excellent. A slight slip occurs on page 123, where "melangeur" is incorrectly spelled several times. There is a good index. ROBERT H. BRADBURY.

ALLEN'S COMMERCIAL ORGANIC ANALYSIS. Edited by W. A. Davis and S. P. Sadtler. Published by P. Blakiston, Philadelphia. Vol. iii, 635 pages (14.5 x 23 cm.). Price, $5. Vol. v, 704 pages (14.5 x 23 cm.). Price, $5.

Vol. iii is devoted to hydrocarbons (aromatic and aliphatic), phenols, aromatic acids, and modern explosives.

Vol. v begins with a section of about 100 pages on tannins. The remainder of the volume is devoted chiefly to natural and artificial dyestuffs, which receive an extremely elaborate and detailed treatment. Both volumes have been completely rewritten and brought abreast of the present state of the subject. The work contains a good deal of descriptive matter, not strictly analytical in character. This, however, will not be without its value for those who use it.

It is sufficient to call the attention of chemists to the continued appearance of this standard work. The publication of the final volumes, dealing with amines, alkaloids, and proteins, is promised as early "as is consistent with good work." ROBERT H. BRADBURY.

A BRIEF LABORATORY GUIDE FOR QUALITATIVE ANALYSIS. By Arthur E. Hill. 76 pages, 12mo. Price, $1. Published by Chemical Publishing Company, Easton, Pa.

When a teacher has developed a course which suits him, there is a natural tendency to make a book of it. This tendency, rather than the meagre financial rewards of authorship, explains the great overproduction of elementary text-books of General Chemistry and of Qualitative Analysis, which are published in numbers out of all proportion to the demand.

The present book is intended for engineering students, who can devote only a short time to the subject. The hydrochloric acid group is omitted. Hydrogen sulphide is the first group-reagent, and both the residue and the solution from the nitric acid treatment of the sulphides are tested for silver. It is at least questionable whether this procedure as a working scheme is an improvement on the usual method. Furthermore, the separation of silver, lead, and mercurous chlorides is so simple and typical that it serves a useful academic purpose, in familiarizing the beginner with the fundamental notions on which all separations depend.

Another debatable novelty is the exclusion of cadmium and strontium, which the author seems to regard as rare elements. The nitroso naphthol method is employed for the separation of nickel and cobalt.

The book is clearly written and should prove useful to the class of students for whom it is intended. The price seems high.

ROBERT H. BRADBURY.

QUANTITATIVE CHEMICAL ANALYSIS. Adapted for use in the laboratories of colleges and schools by Frank Clowes and J. B. Coleman. Ninth edition, 565 pages, illustrations, 8vo. Price, $3.50. Published by P. Blaikiston's Son & Co., Philadelphia.

This book is intended for beginners in universities and technical schools. The authors take the point of view that what the student needs, in his laboratory manual of quantitative work, is the detailed practical directions which will enable him to do the work accurately. Practically no theoretical information is given. Equations only appear when they are needed in calculation, and no reference is made to the ionic equilibria involved or, in fact, to physico-chemical ideas of any sort. In fact, it must be confessed that the scrappy treatment of such matters in a work devoted to Quantitative Analysis is of doubtful value. The student who is making a serious study of the subject should be nearly ready to attack a book like Ostwald's "Scientific Foundations of Analytical Chemistry," in which the basis of his work is given a dignified, coherent treatment.

The present book is an excellent laboratory manual. The directions are precise, detailed, and clear, and are evidently the result of long experience with the methods.

The book is unusually free from errors and oversights. On page 83 a rather singular effect is produced by directing the student to fuse zinc-blende with sodium peroxide in a platinum crucible and informing him, in a note, that he will probably spoil his crucible if he does this.

The statement on page 207, that the iron can always be completely extracted from an iron ore by heating with hydrochloric acid until the residue appears colorless, is hardly correct. Such residues often yield notable quantities of iron when fused with sodium carbonate and taken up with hydrochloric acid.

These, however, are very minor points. This is an excellent book which can be put into the hands of the student with confidence and which might, with advantage, take the place of many a needless course of lectures on the subject.

ROBERT H. BRADBURY.

PUBLICATIONS RECEIVED.

Flashlight Portraiture. A book of common sense information and practical methods of making portraits by flashlight at home or in the photographic studio. 46 pages, illustrations, 12mo. New York, Tennant & Ward, no date. Price, in paper, 25 cents.

Dark-Room Work. A practical dark-room manual, with suggestions as to equipment, working conveniences, short cuts, and handy methods of dark-room work. 62 pages, illustrations, 12mo. New York, Tennant & Ward, no date. Price, in paper, 25 cents.

U. S. Bureau of Standards, Circular No. 32. State and Municipal Regulations for the Quality, Distribution, and Testing of Illuminating Gas. 133 pages, 8vo. Washington, Government Printing Office, 1912.

U. S. Department of Agriculture. Office of Public Roads, Bulletin No. 43. Highway Bridges and Culverts. By Charles H. Hoyt, C.E., and William H. Burr, C.E. 21 pages, illustrations, 8vo. Washington, Government Printing Office, 1912.

U. S. Bureau of Mines, Bulletin No. 23. Steaming Tests of Coals and Related Investigations, September 1, 1904, to December 31, 1908. By L. P. Breckenridge, Henry Kreisinger, and Walter T. Ray. 380 pages, illustrations, plates, 8vo. Washington, Government Printing Office, 1912.

U. S. Coast and Geodetic Survey. Results of Observations made at the Coast and Geodetic Survey Magnetic Observatory at Cheltenham, Maryland, 1909 and 1910. By Daniel L. Hazzard. 93 pages, plates, 4to. Washington, Government Printing Office, 1912.

Iowa State College. Engineering Experiment Station Bulletin No. 25. Electric Power on the Farm. By Adolph Shane. 63 pages, illustrations, 8vo. Ames, Iowa.

U. S. Department of Agriculture. Bureau of Chemistry, Circular No. 96. A Measurement of the Translucency of Papers. By C. Frank Sammet. 3 pages, 8vo. Washington, Government Printing Office, 1912.

U. S. Bureau of Standards. Technologic Papers No. 3. Tests of the absorptive and permeable properties of Portland cement mortars and concretes, together with tests of damp-proofing and waterproofing compounds and materials. By Rudolph J. Wig, associate engineer-physicist, and P. H. Bates, chemist. 127 pages, illustrations, plates, 8vo. Washington, Government Printing Office, 1912.

Simultaneous and Cyclic Appearances of Epidemics of Pneumonia, Grip and Enteritis on the Northern Hemisphere, and Their Synchronism with Solar Activity Cycles. By C. M. Richter, M.D., San Francisco. 11 pages, tables, 8vo. Chicago, American Medical Association, 1911.

U. S. Geological Survey. Potash Salts, Summary for 1911. By W. C. Phalen. Advance Chapter from "Mineral Resources of the United States, calendar year 1911." 31 pages, 8vo. Washington, Government Printing Office, 1912.

University of Michigan. Nineteenth Summer Session. Abridged announcement 1912. 15 pages, illustrations, 12mo. Ann Arbor, University, 1912.

U. S. Department of Agriculture, Bureau of Chemistry, Bulletin No. 144. Wood Turpentine: its Production, Refining, Properties, and Uses. By F. P. Veitch and M. G. Donk. 76 pages, illustrations, 8vo. Washington, Government Printing Office, 1911.

U. S. Bureau of Standards. Technologic Papers No. 5. The effect of high-pressure steam on the crushing strength of Portland cement mortar

and concrete. By Rudolph J. Wig. 25 pages, illustrations, plates, 8vo. Washington, Government Printing Office, 1912.

U. S. Department of Agriculture, Bureau of Chemistry, Circular No. 85. A Modification of the Herzfeld-Bohme Method for the Detection of Mineral Oil in Other Oils. By F. P. Veitch and Marion G. Donk. 15 pages, illustrations, 8vo. Washington, Government Printing Office, 1912.

Chicago Pneumatic Tool Company. Catalogue No. 37—Stone Tools. 23 pages, illustrations, 8vo. Catalogue No. 40—Rockford Railway Motor Cars. 24 pages, illustrations, 8vo. Bulletins 8–19, E–20, E–21, E–23. Chicago, Company, 1912.

Cadmium in the United States. C. E. SIEBENTHAL. (*Brass World,* viii, 3, 89.)—Up to 1910 no cadmium was produced in this country except at one zinc smelter, where it is recovered as a by-product. Now two companies are producing it, as can be learned from the advance pamphlet, "Zinc and Cadmium in 1910," of the "Mineral Resources of the United States": "The American Smelting and Refining Company began the production, in 1910, by the recovery of a few hundred pounds at the Globe smelter in Denver, Col. It is reported that the cadmium is recovered from the flue dust. No details of the methods employed have been made public. It is reported that furnaces are under construction which will have an output of about 1,000 pounds of cadmium per month. It seems likely that the source of the metal lies in the zinciferous lead ores from Leadville, Col., and similar ores."

British Standard Definitions of Yield-point and Elastic Limit. (*Mech. Eng.,* xxix, 67.)—The sectional committees of the Engineering Standards Committee dealing with the specifications for steel and wrought iron have agreed upon the following definitions for the elastic limit and yield-point: "*Elastic limit* is the point at which the extension ceases to be proportional to the loads. In a stress-strain diagram plotted to a large scale it is the point where the diagram ceases to be a straight line and becomes curved." "*Yield-point* is the point at which the extension of the bar increases without increase of load." For practical purposes the yield-point is defined as the load per square inch at which a distinctly visible increase occurs in the distance between gauge points as determined by dividers, or at which there is a distinct drop of the lever or of the gauge pointer in hydraulic machines. It is pointed out that the elastic limit can only be determined by the skilful use of very delicate instruments, making its determination impracticable for commercial testing. The Ships Committee supports the method of fixing by experience the working stress as a proportion of the ultimate stress, rather than as a proportion of the elastic limit or yield-point.

CURRENT TOPICS

Production of Solid Oxygen by the Evaporation of the Liquid. J. DEWAR. (*Roy. Soc. Proc.*, A85, 589.)—Owing to its small vapor pressure at the melting point, it is not possible, with ordinary air-pumps, to obtain solid oxygen by evaporation of the liquid, as is the case with hydrogen or nitrogen. If, however, pure liquid oxygen, contained in a properly-isolated vessel, be subjected to the exhaust produced by a quantity of charcoal kept at about the temperature of boiling oxygen, the pressure is lowered to such an extent that the oxygen solidifies to a transparent jelly. The vapor pressure at the melting point appears to be between 1.115 and 1.125 mm. Taking 1.12 mm. as correct, the melting point of oxygen as calculated by the method of Rankine or Willard Gibbs is 53° to 55° absolute. A direct determination of the melting point by means of a small hydrogen gas thermometer gave the value of 54° absolute.

Boundary Waves and Parallactic Tides. O. PETTERSON. (*Eng.*, xcii, 384.)—One of the most notable features of the eastern side of the North Sea, the Skagerrak, Kattegat, and Baltic is the stratification of the water in layers of different origin, distinguishable by differences in temperature and salinity. The boundary between two layers could be located by means of floats, and the currents indicated photographically by a special water-gauge and current-measurer made by Ericson & Co., Stockholm. Records are made every half-hour for periods of fourteen days. The phenomena are ascribed to secondary effects from the ocean tides in deep water outside the shallow basins.

Copper Losses in Rotary Converters. J. R. CARSON. (*Electrical World*, lviii, 748.)—A general formula is given for the copper losses in a rotary converter not only for any number of phases but also for any power factor. The assumption is made that the efficiency of the converter is 100 per cent. The formula is illustrated by tables, the relative ampère rating at different power factors being given.

A New Anti-Friction Metal. ANON. (*Brass World*, vii, 10, 356.)—This consists of zinc 78 per cent., copper 12, lead 7, iron 2, and manganese 1 per cent. Its anti-frictional qualities enable it to replace more expensive metals for bearings, bushings, and numerous other castings. It holds its lustre for a long time. The components being of an anti-frictional nature make it less subject to the action of heat, and therefore less lubrication is necessary.

Prize Offered by the New Zealand Government in Connection with New Zealand Hemp. ANON. (*Engineering*, Dec. 29, 1911.)—The New Zealand Government has agreed to pay £12,000 as a bonus or bonuses for improvements in connection with:

(1) The extraction and dressing of fibre from the New Zealand hemp plant (*Phormium tenax*); or

(2) The utilization of the by-products obtained during the process of extracting the fibre; on condition that the machine or process in regard to which the whole or any part of the bonus is to be paid shall be recommended by the New Zealand Flax-Millers' Association, and approved by the Government.

The £12,000 will be paid wholly or in part for any of the following, *viz.*:

(1) A process of extracting and dressing the fibre of New Zealand hemp (*Phormium tenax*), whether by machinery or otherwise, whereby there shall be obtainable (*a*) a greatly-improved quality of fibre marketable at a higher price, or (*b*) a substantial reduction in the cost of producing the fibre.

(2) Any such process that shall produce a fibre fit for use in manufactures other than rope and twine spinning.

(3) Any such process that shall render unnecessary any of the present operations involved in extracting and dressing the fibre, such as stripping, paddocking, or scutching.

(4) Any improved method of separating the green envelope or the flinty or colored matter from the green leaf of the phormium plant so as to produce a strong white fibre, the whole of which can be saved with little or no tow or waste.

(5) Any means whereby the by-products obtained during the processes of extracting and dressing New Zealand hemp-fibre—such as the gum, dye, stripper-slips, tow-dust, or waste vegetable matter—shall be converted into a marketable commodity.

Applications for the bonus must be addressed to the President of the New Zealand Flax-Millers' Association, Palmerston North, New Zealand, and must reach him not later than noon of November 30, 1913. They must be inclosed in an envelope clearly marked "Application for Bonus."

Each applicant shall state what lump sum (including the bonus of £12,000 or any part thereof) would be required to purchase the New Zealand rights of his machine or process in the event of such rights being acquired by the New Zealand Government for free use by the hemp-millers of this Dominion; or, if applicant is unwilling to sell his rights, he shall state what amount of bonus (not exceeding £12,000) and what royalty he would require for the use of his machine or process.

Brass Foundry Mixtures. E. S. SPERRY. (*Brass World*, viii, 2, 41.)—For "*Composition*," a term generally employed in brass

foundries to designate any metal that is red, casts well, and cuts freely.

Mixture.		A cheaper mixture.	
Copper	85	Copper	85
Tin	5	Tin	3
Zinc	5	Zinc	9
Lead	5	Lead	3

Statuary Bronze.—The best metals obtainable are selected and the best mixture known is always employed for statuary, on account of the enormous expenditure for labor, which forbids any economy in metal. The mixture is:

Copper	90	Zinc	3
Tin	6	Lead	1

The small quantity of lead is necessary to impart the required chasing qualities to the statue.

Mixture for trolley wheels:

Copper	92	Zinc	2
Tin	6		

No lead is used here, as it has been shown that this mixture gives a far greater mileage than one which contains lead.

Mixture for pattern castings:

Copper	88	Zinc	2
Tin	8	Lead	2

Good metals are necessary for pattern bronze. They come out of the sand bright and clean.

Preservatives for Butter and Margarine. K. FISCHER AND O. GRUENERT. (*Zeit. Unters. Nahr. Genussm.*, xxii, 553.)—The results of numerous experiments showed that common salt is the best preservative of butter and margarine. Specimens containing 3 per cent. of salt were quite fit for consumption after the lapse of three months, whilst other specimens which had been treated with benzoic acid, salicylic acid, boric acid, etc., had rapidly become rancid. With the use of salt the decomposition of the fat and casein was practically, though not quite, inhibited, but the other preservatives failed to stop this decomposition even when (in the case of butter) as much as 1 per cent. was added.

Light Emitted by Fireflies. P. SINGH and S. MAULIK. (*Nature*, lxxxviii, 111.)—A number of fireflies were placed over a photographic plate and various materials interposed. The plate was affected through thin layers of wood and leather, but not appreciably through glass. Thus the rays emitted by fireflies are in some respects analogous to Röntgen rays and ultra-violet light.

Arc Lighting. C. P. STEINMETZ. (*Gen. Elec. Rev.*, xiv, 568.)—In neither the flame arc nor the luminous arc is the light a temperature effect; it more nearly corresponds to a direct conversion of electrical energy into light, *i.e.*, "luminescence." The light is given by the vapor stream which conducts the current across the gap between the terminals, and not by the tips of the terminals, as in the old carbon arc. The *flame* arc is a carbon arc whose vapor stream is made luminous and light-giving by introducing into it mineral compounds, mostly calcium salts. The electrodes are impregnated with these salts. The light-giving current is conducted by the carbon vapor, but not by the salts. In the *luminous* arc the light-giving material is used as the vapor conductor. Iron and titanium compounds which are embodied in the negative electrode are mostly used. The composition of the positive electrode is immaterial and is usually made non-consuming by making it large enough to keep cool. In the flame arc the positive electrode must always be an impregnated one. The color of the flame arc is yellow (calcium) and the luminous titanium arc white. The luminous arc is better suited than the flame arc for low-power lighting units. The temperature of the luminous arc is about 2000° C., that of the flame arc about 3700° C. The efficiency of the yellow flame arc is 0.20 to 0.33 watts per candle, that of the luminous arc 0.33 to 0.50, and that of the tungsten incandescent lamp 0.80 to 1.25 watts per candle. The application of these three illuminants to street and indoor lighting is discussed in detail.

Photosensitive Antimonite Cells. W. S. GRIPPENBERG. (*J. Am. Chem. Soc.*, xxxiii, 1761.)—Antimonite (stibnite) has been shown by F. M. Jaeger to suffer a change of its electrical condition upon exposure to light and to possess certain advantages over selenium for the construction of photosensitive cells. A cell was made by clamping together a thin lamella of antimonite and a small grate of very small, thin strips of gold or platinum foil. Such cells have a resistance between 10^5 and 5×10^6 ohms, are very sensitive, and may be used without trouble with a potential difference of 30 volts.

Commercial Preparation of Pure Nitrogen. G. CLAUDE. (*Comptes Rendus*, cliii, 764.)—Nitrogen 99.9 per cent. pure is obtained by a modification of his air-liquefaction apparatus, by re-evaporating about one-third of the impure liquid nitrogen and washing it in a liquid still containing 4 per cent. of oxygen. Two apparatuses of this type, each supplying 400 cm. per hour of 99.7 per cent. nitrogen, are installed at the Societa Italiana Carburo di Calcio, at Terni; and two more for 500 cm. per hour of 99.8 per cent. nitrogen are installed at the Alby Carbidfabriks.

General Law Concerning the Behavior of Solid Bodies at Very Low Temperatures. W. NERNST. (*Physik. Zeit.*, xii, 976.)—Recent investigations of specific heats, in accordance with the requirements of the theory of energy units, made it certain that for every solid body there is a certain range of temperature from absolute zero upwards in which the conception of temperature practically loses its significance. Within this range every property which is determined by the mean behavior of the atom must be independent of the temperature. This rule may be considered firmly established in the cases of the following properties: volume, specific heat, thermal coefficient of expansion, compressibility, and the free energy and total energy changes of a reaction. The opinion is expressed (but with some reserve, because strong proof is yet wanting) that the thermal condition of metals is finite and independent of temperature for a certain range above absolute zero, and that thermo-electric force and the Peltier effect approach zero as the temperature approaches absolute zero.

Infected Tin or the "Tin-Pest." PROF. ERNST COHEN. (*Brass World*, viii, 3, 96.)—This paper considers the decay of tin, and the results may be thus summarized: (1) That metallic tin exposed to a low temperature will gradually change to the allotropic or gray form of tin in the shape of powder. Massive tin will become granular. Sheet metal may become perforated by the formation of "tin-pest." (2) The lower the temperature the more rapid the decay of the tin. It should be kept above 18° C. (64.4° C.), which seems to be the point of transition. (3) That the granular, gray tin resulting from the decay of white tin is only an allotropic form of tin, and can be changed to the white form by merely melting. (4) When the tin decays to the gray powder it increases in volume. (5) The decay of tin may be brought about by *infection*. If white tin is brought in contact with a trace of the gray powder, decay takes place at this point and gradually increases in area. This indicates an analogy in metallurgy to that of the diseases of the human race. Metals can become diseased by infection as one person may become infected by another.

Nomenclature of Alloys. W. ROSENHAIN. (*Inst. of Metals*, Jan., 1912.)—Attention is called to the confusion in the nomenclature of alloys, particularly in the use of the terms "brass" and "bronze," which are frequently used in contradiction. A system of classification is suggested in which the class name "brass" shall include all alloys whose principal constituents are copper and zinc; and "bronze" those consisting of copper and tin. When other metals are present each particular alloy is distinguished by an addition to the class name; for instance, so-called manganese bronze would be known as manganese brass, and "Aich metal" as iron brass.

Blau Water Gas for Industrial Purposes. A. MEADE. (*J. Gas Lighting*, cxvii, 83.)—The industrial use of water gas has made considerable progress on the continent of Europe. Its most important property is its very high flame temperature. With preheated air, a temperature above the melting-point of platinum is reached, and under ordinary conditions the hottest part of the flame is between 2800° and 3000° F. Burned at a pressure of ½ pound per square inch, with air at 2½ pounds, in a fire clay faced burner, it is used for pipe welding. For heating purposes it is unnecessary to purify it from hydrogen sulphide, but this must be done for lighting and power purposes. Blau water gas is not very suitable for gas engines, as it contains so much hydrogen that it cannot be highly compressed. With suitable appliances the results obtained for incandescence lighting are equal or superior to those obtained with ordinary coal gas. It is also used for the preparation of hydrogen by liquefying or freezing out the other constituents, and by cement manufacturers to heat their rotary furnaces.

Design of Thirty-Ton Induction Furnace. A. HIORTH. (*Amer. Electrochem. Soc. Trans.*, xx, 293.)—From experiments with his 5-ton monophase furnace at Jossingfjord, the resistance of the furnace and the bath is estimated. The liquid iron seems to have a resistance of 1.4 ohms per square mm. per metre in length; higher estimates, up to 1.7 ohms, are probably more correct. The power factor was 0.81 with a charge of 3 tons, 0.73 with 4, 0.65 with 5, and 0.6 with a charge of 6 tons. The 30-ton furnace is to be 3-phase. With 12.5 cycles, cos ϕ would be 0.34; with 10 cycles, 0.41; with 8 cycles, 0.5; with 5 cycles, 0.67. He decides upon 8 cycles and one generator yielding 3,540 ampères at 230 volts, and occasionally up to 4,300 ampères. Unger thought that several smaller generators would be preferable to one large unit at the low periodicity.

Reduction of Power Consumption in Electric Steel Furnaces. DR. C. HERING. (*Metal. and Chem. Engin.*, ix, 590.)—On the basis of Hiorth's figures (see preceding note) and those supplied by Röchling-Rodenhauser, Dr. Hering calculates the electric energy which should suffice to keep the temperature of the fused steel constant. This energy would be 26 k.w. per ton for steel furnaces of a capacity of 0.5 ton, 9.5 k.w. for 10-ton furnaces, and 5.5 k.w. per ton of steel for 50-ton furnaces. These figures should be realized with suitable construction.

Increasing the Ductilily of Tungsten. (*Brass World*, viii, 3, 105.)—Metallic tungsten is now used to such an extent in electric lamps that any method of improving its quality becomes valuable. Werner von Bolton, of Charlottenburg, Germany, the inventor of the tantalum electric lamp, has patented a method of increasing the

ductility of tungsten so that it can be made into wire for lamp filaments. The tungsten is treated at red heat with a mixture of hydrogen and sulphur chloride. This removes any tungsten oxide, which is a cause of brittleness. The oxide is converted into sulphide, and the sulphide reduced by hydrogen. The purified metal contains some sulphur, which is expelled by heating to whiteness in a vacuum furnace, and pure metallic tungsten of great ductility is obtained, which can be easily drawn into wire. If the tungsten oxide is reduced directly by hydrogen, some hydrogen is left in the metal and causes brittleness.

Crucibles for Melting Platinum. (*Brass World*, viii, 3, 82.)—Lime has been found the most satisfactory material for crucibles for melting platinum. It is about the only material that will stand the high heat of the oxy-hydrogen blow-pipe. Pieces of burned lime are selected as free from fissures and foreign matter as possible. A cavity is cut in these pieces to hold the platinum, which is melted in the cavity by an oxy-hydrogen blow-pipe; it is then allowed to cool. The button of platinum is hammered until it is thin enough to enter a pair of rolls to be rolled into sheet.

Molybdenum Steel in lhe Electric Furnace. E. J. DITTUS and R. G. BOWMAN. (*Amer. Electrochem. Soc. Trans.*, xx, 355.)—The iron is fused under coke, sand, and lime and a mixture of molybdenite, M_0S_2, and ferrosilicon is added. A good steel with 0.6 per cent. carbon, 1.15 molybdenum, 0.37 sulphur, 0.08 phosphorus, and 0.9 Si was obtained. The furnace was a deep crucible, into which two electrodes were lowered; these were either coupled in series or coupled in parallel, when a bottom electrode formed the other terminal. The second arrangement was preferable.

Struverite, a Rare Tantalum Mineral. ANON. (*Bull. Imp. Inst.*, ix, 354.)—A specimen of a lustrous black mineral, found in the Kuala Kangsar District, Perak, in the Federated Malay States, was found to consist of the rare mineral strüverite, essentially an isomorphous mixture of tapiolite (iron tantalate) and rutile. The sample, freed from foreign admixtures, analyzed titanium dioxide 45.74 per cent. tantalum oxide 35.96 per cent., niobium oxide 6.90, ferrous oxide 8.27, manganese oxide, trace, stannic oxide 2.67, silica 0.20, water 0.50 per cent. It is considered that strüverite could be utilized as a source of tantalum, though it would have to be used at a lower rate than tantalite, as it is poorer and more expensive to smelt.

Production of Helium by Radium. B. B. BOLTWOOD and E. RUTHERFORD. (*Akad. Wiss. Wien. Sitz. Ber.*, cxx, 2a, p. 113.)—An extended determination of the volume of helium produced from a large quantity of radium showed that approximately 156 mm. per

gramme of radium in equilibrium with its disintegration products to radium C was produced. This observed rate of production of helium closely agrees with the rate calculated from the counting experiments of Rutherford and Geiger (158 cub. mm. per year), thus proving that the α particle during its flight consists of a helium atom carrying two unit positive charges and that helium itself is monatomic. The agreement of the observed and calculated values is independent of the purity of the Ra-standard employed, as the same standard has been used in both measurements. Determinations of the amount of helium produced by the disintegration of a known quantity of radium emanation were also made, and found to agree with theory. The production of helium by polonium and from a preparation containing radio-lead was also observed.

Economic Working of Steam Boilers. C. W. JORDAN. (*Mech. Eng.*, xxviii, 626.)—This paper refers to the difficulties connected with the regulation of combustion, and on the point of excess of air admitted to the furnace it is said that the ordinary water column draught-gauge gives indications of two causes of movement, *viz.*: (1) the pressure necessary to produce the desired velocity of air flowing through the grate, and (2) the pressure necessary to secure the flow of the fuel gases through the flues, etc., the one being dependent upon variable and the other upon constant conditions. A means is proposed of measuring the second one alone by the use of a differential water column. The regulation of the feed water has been much neglected, and an auto-electric apparatus is proposed for the purpose of controlling the feed; this apparatus is described and illustrated. It is dependent upon a float, the rod of which carries an iron bar forming the armature of an electro-magnet. When this armature is brought by the water level into the magnetic field it is held so as to close the circuit of an electro-magnet operating the field valve. The first magnet is cut out of circuit by the rising of the float, and the feed valve closes. Other details conducive to economical working are also discussed.

Iron Content of Cow's Milk. F. EDELSTEIN and F. V. CSONKA. (*Biochem. Zeits.*, xxxviii, 14.)—The figures previously given for the iron content of cow's milk range from 1 to 15 mgm. of iron per litre. It is now found that if the milk be drawn into glass vessels the iron content is 0.4 to 0.7 mgm. per litre, or from one-third to one-half that of human milk. In ordinary mixed dairy milk and in purchased milk the iron content was higher, 0.7 to 1.5 mgm., and less constant.

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